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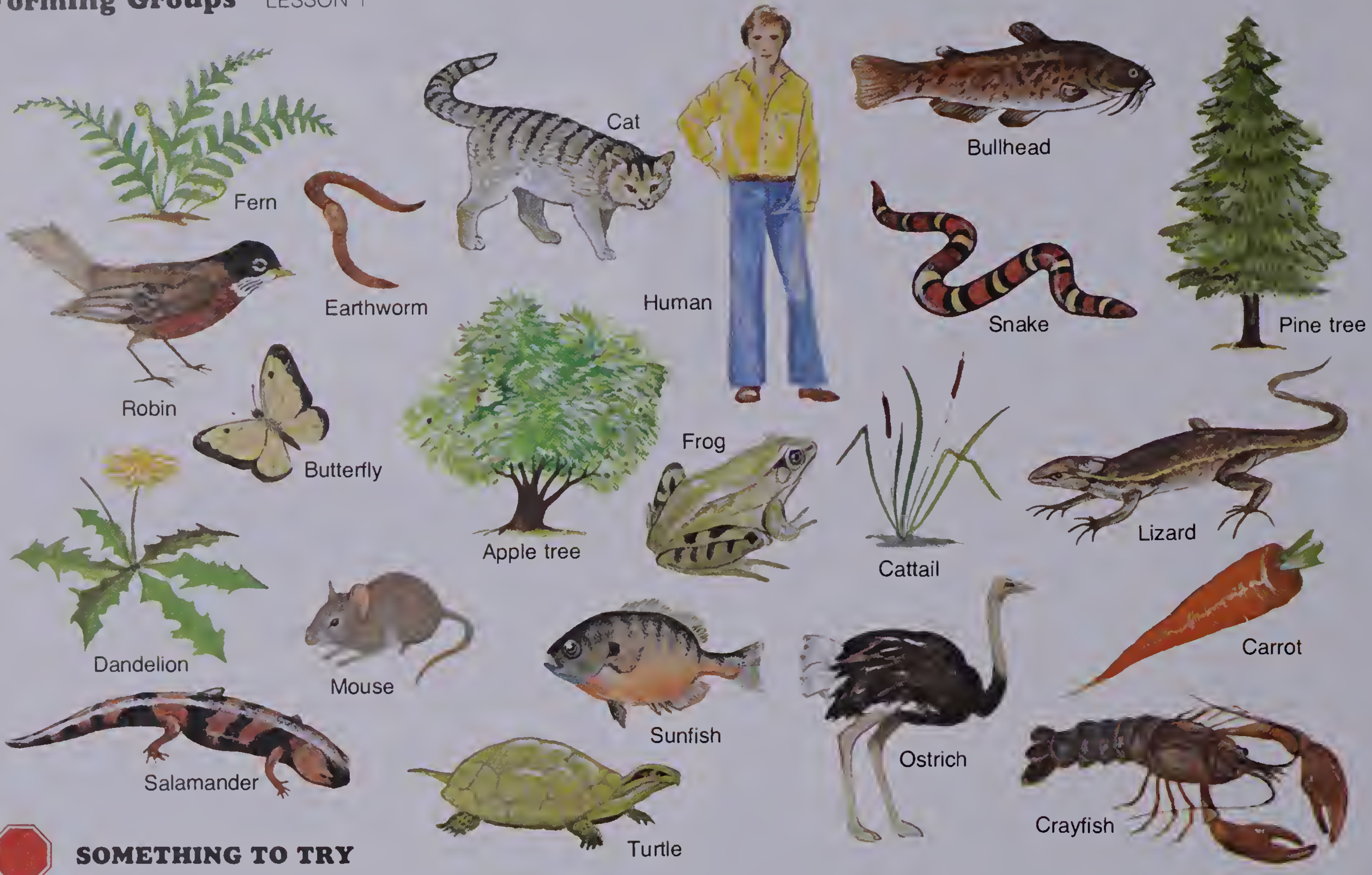
1 Classifying Living Things

Suppose the things in a store were all mixed up. How could you find what you wanted? How could a clerk tell you where to look? How would the manager know when the store was out of something? A store could not be run this way. The things being sold must be arranged carefully.

In this store, things are placed in groups. Meats are together. Baked goods are together. Spices are together. Fresh vegetables are in one part of the store. If you wanted to find something, you could tell where to look. If you asked for something, the clerk could give you clear directions. Orderly grouping makes it easier to work with things.



SOMETHING TO TRY

1. Try to sort out all these *organisms* into just two groups. "Organism" is the scientific word for a living thing. Write the names in two lists so that all the organisms in each list are alike in some way. Compare your lists with those of a classmate. Are they the same? How are they different?

2. Sort the organisms again, making more than two groups. What is the best way you can think of? Is this the same way your neighbor did it?

Is there one best way to sort living things into groups? What makes you think so? What does your neighbor think about this?

When people know how one TV set works, they probably know how many TV sets work. If they can fix one kind, they can usually fix another. There may be small differences between TV sets, but they are alike in many ways.

In an orderly group, knowing about one member of the group helps to know about the others. Often, knowing about one object can mean knowing some things about many others.

OUR SET IS NOT DYNA-VISION
DYNA-VISION
ONE TV SET WORKS LIKE ANOTHER. I CAN FIX IT.

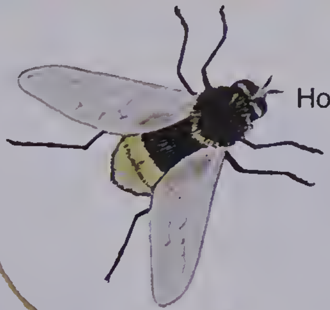
Groups of organisms. In the same way, knowing a group of organisms helps you to know about its members.

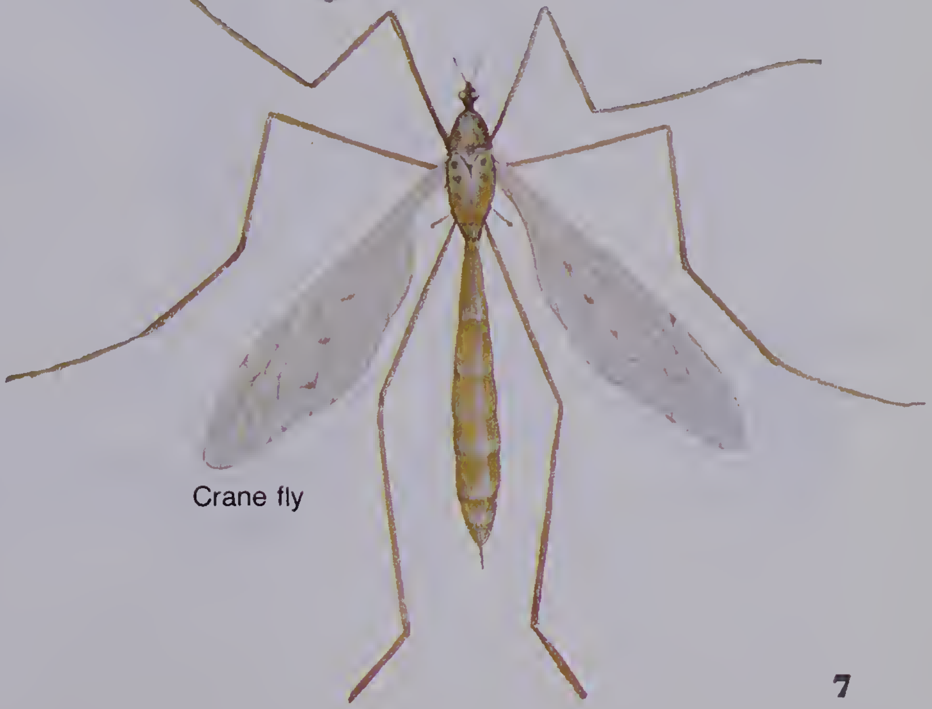
Suppose you wondered if a buzzing insect could sting. Is there a way to tell whether an insect can or cannot sting?

Suppose that stinging insects belong to one group. Knowing what that group looks like will help.

The insects on this page are members of a group called flies. There are thousands of different kinds of flies. But all flies are alike in some ways. Look carefully at these two. In what ways are they alike? How are they different?

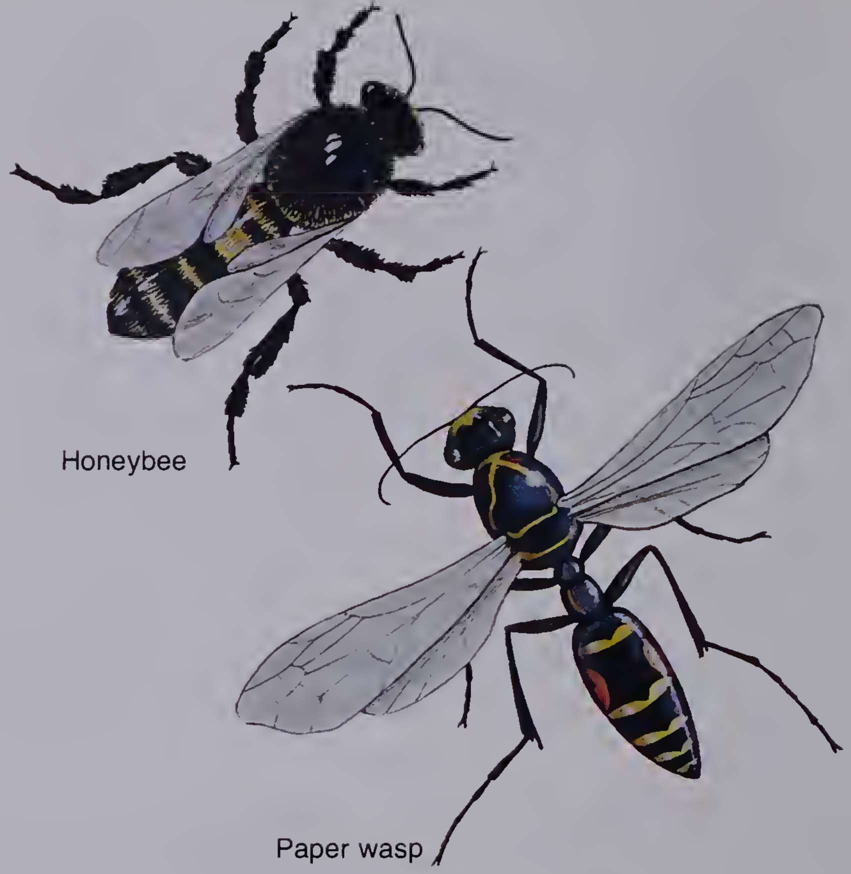
Flies do not sting. Some bite, and a bite can hurt or itch. But flies do not bite to protect themselves. They bite only to get food.

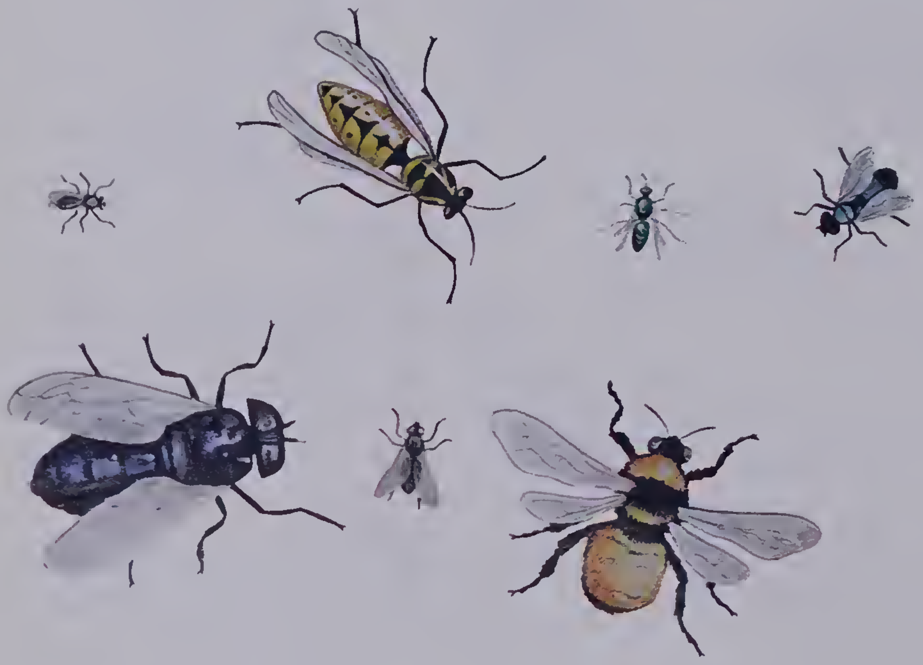

Hover fly

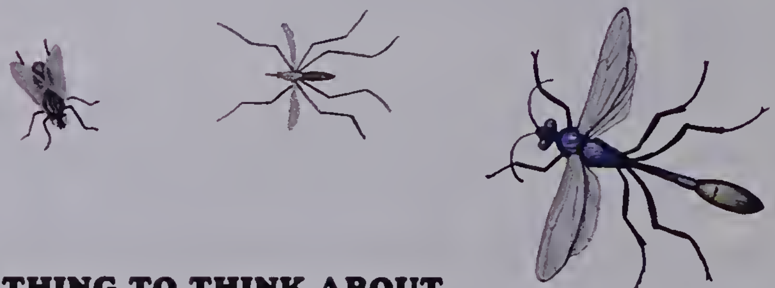

Crane fly

Some bees and wasps can sting. Sometimes they sting to protect themselves. But mostly they sting another insect or spider so it cannot move. Then it becomes food for young bees or wasps.

There are thousands of different bees and wasps. All of them are alike in some ways. Look carefully at this bee and this wasp. In what ways do they look alike? In what ways do they differ? How could you tell a bee or wasp from a fly?







SOMETHING TO THINK ABOUT

Here are some common flies, bees, and wasps. Which of these insects do you think could sting? Which ones probably could not sting? What makes you think so?

Vertebrates LESSON 2

Suppose you were asked to sort all animals into large, then smaller, groups. How would you begin? What would be the first step?

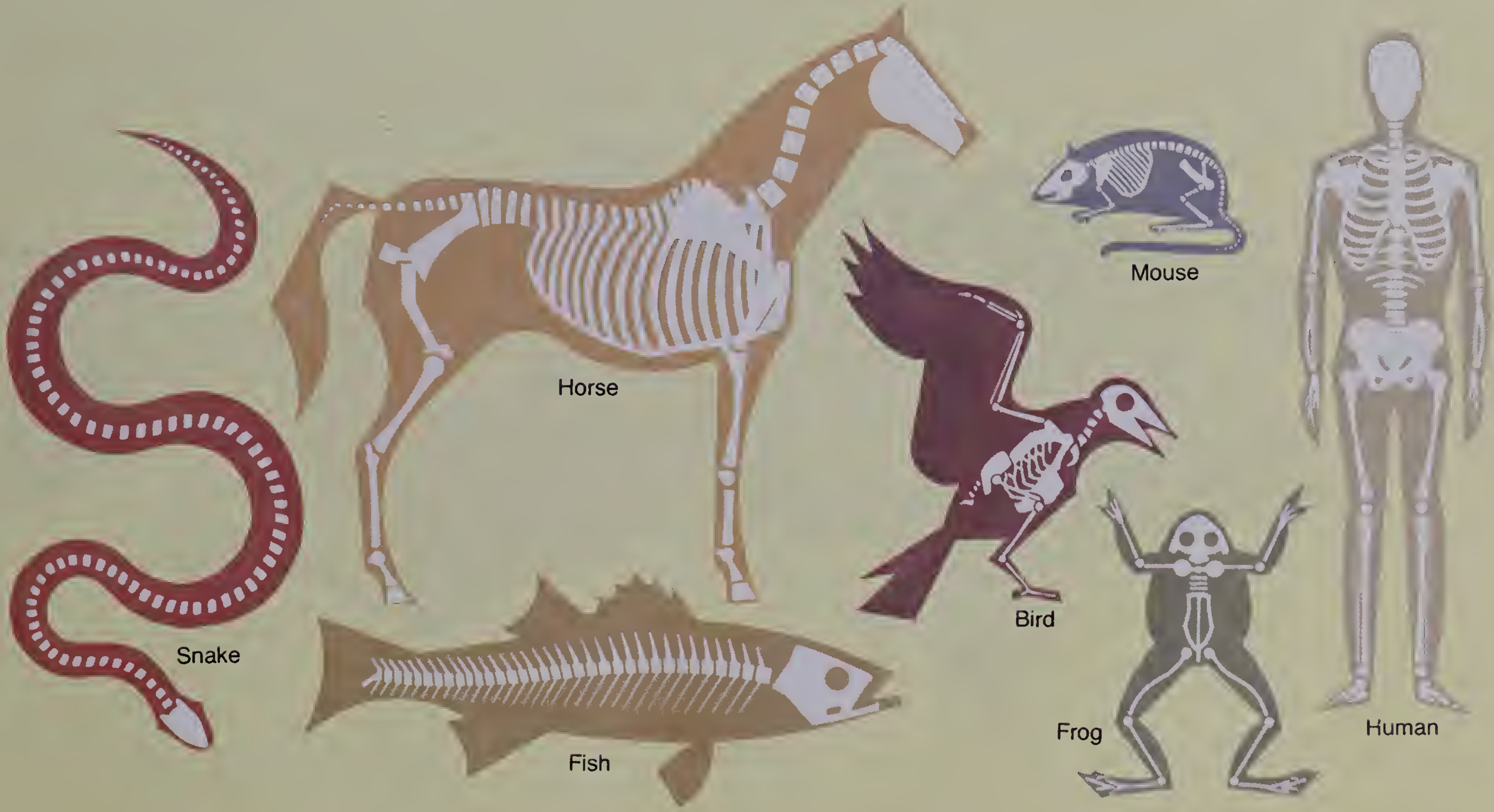
Animals with a backbone. One way is to separate all animals into two groups

- those with a backbone
- those without a backbone

Humans belong to the group with a backbone.

Inside your body is a bony skeleton. Your backbone is part of this skeleton. Horses, birds, snakes, frogs, and fish all have a backbone, too.

The backbone is not a single bone. Instead, it is made up of several bones called *vertebrae*. An animal with vertebrae is a *vertebrate*. Dogs, cats, and robins are vertebrates. You are a vertebrate. How many other vertebrates can you think of?



SOMETHING TO TRY

Find out what a fish skeleton looks like.

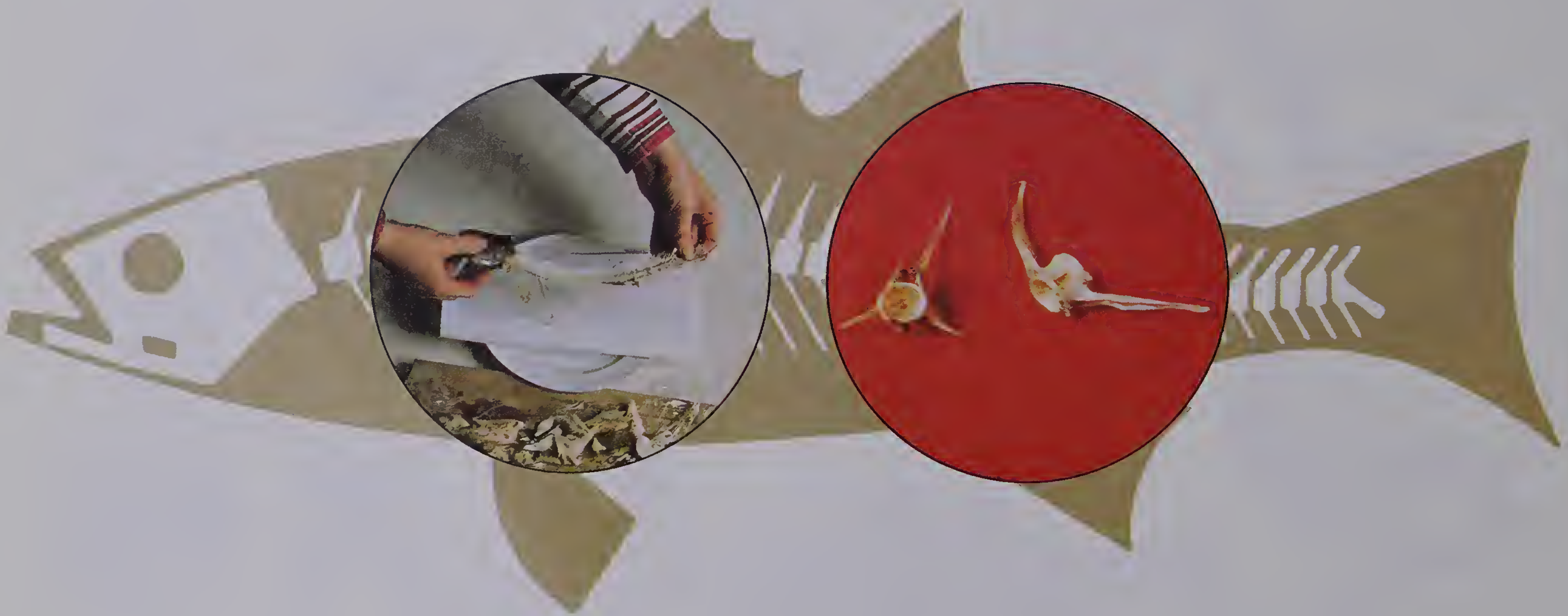
Sometime, if you have a fish for dinner, save the skeleton. Wash it carefully in soapy water and dry it. Then look at it with a magnifying glass.

The line of bumpy bones that runs from end to end is the backbone, or *vertebral column.* In it are many vertebrae. Each *vertebra* is something like a spool with *spines* sticking out of it. Muscles fastened to the spines help the fish to move.

The vertebrae are separated by pads of *cartilage*. These pads let the vertebral column bend.

Break the vertebral column apart near the tail, and separate one vertebra from the rest. Can you see a large opening where the spines come together? This is where the *spinal cord* passed through.

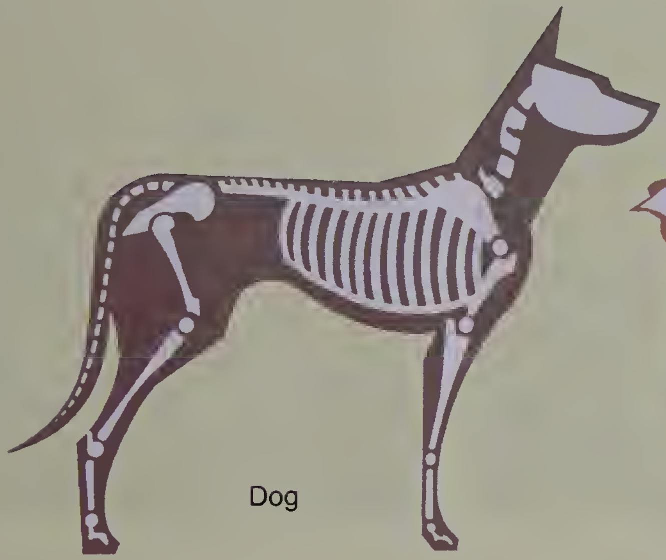
The spinal cord is a bundle of nerves. It connects the brain to other parts of the body. The vertebrae and the spines protect the spinal cord from injury.

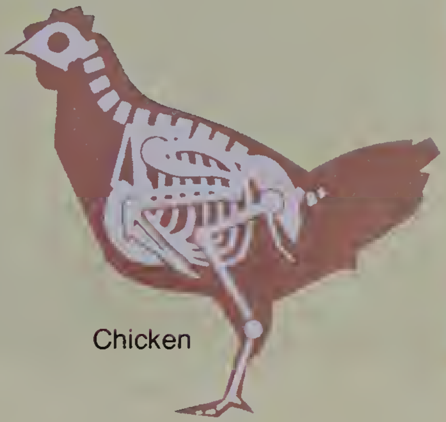


More bones to study. Save the neck from a cooked chicken. Put it in a small pan with just enough water to cover it. Add some vinegar or a spoonful of detergent. Then boil the neck for 10 minutes. This will help to loosen the meat. When the water has cooled, use tweezers to remove as much meat as you can. Rinse off the neck bones and dry them with a paper towel. Now you are ready to study these vertebrae.

In what ways are the neck vertebrae of a chicken like vertebrae of a fish? In what ways are they different?

Can you find the hole through which the chicken's spinal cord might have passed? How is it different from that in a fish vertebra?





Sorting the Vertebrates LESSON 3

Vertebrates have been sorted into five main groups called *classes*. The animals in each class are alike in some important ways.

The five classes of vertebrates are shown on these pages. In what ways does each class differ from the others? In what ways are they alike?

MAMMALS

Bat

Leopard

Human

Porpoise

BIRDS

Seagull

Ostrich

REPTILES

Snake

Lizard

AMPHIBIANS

Frog

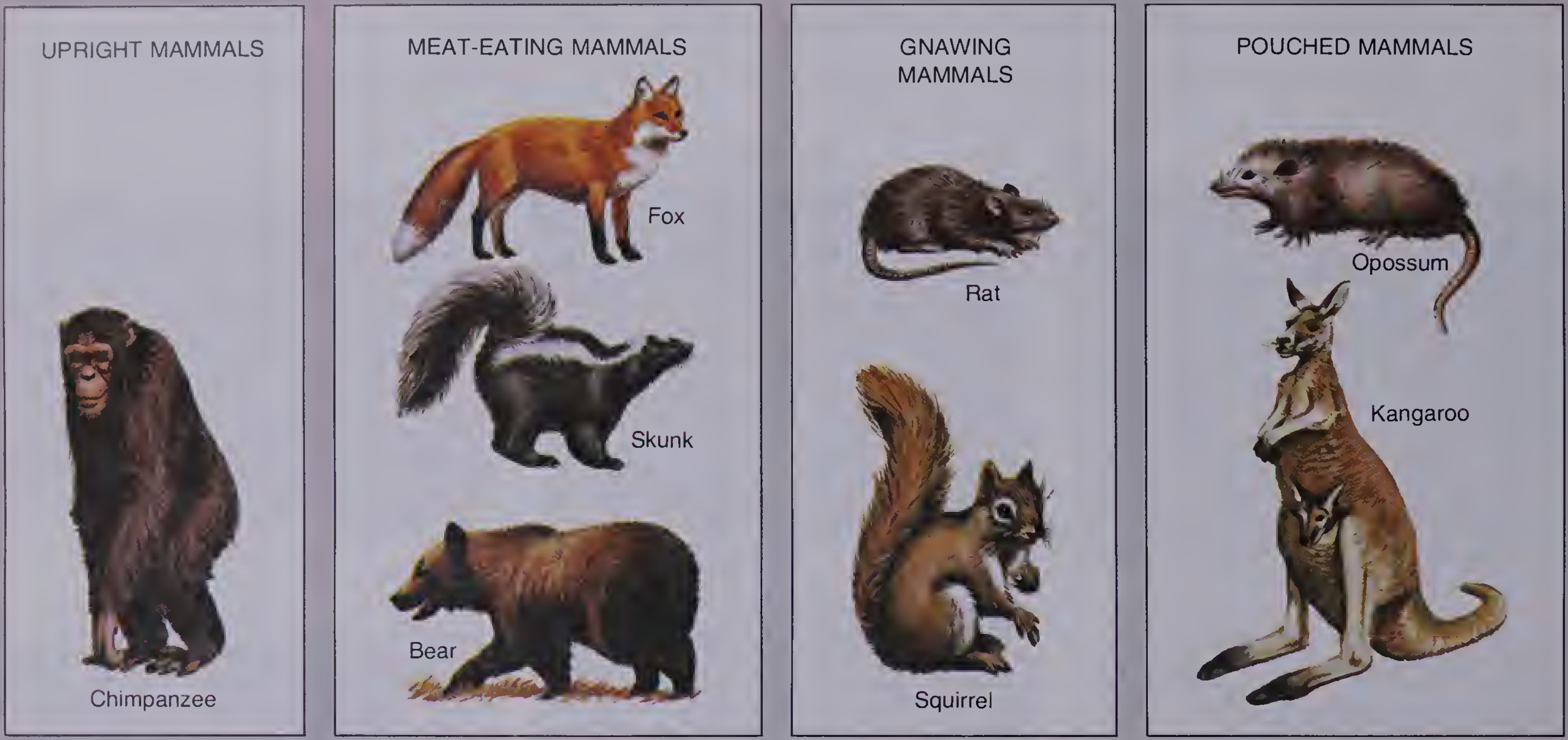
Salamander

FISH

Eel

Perch

SOME GROUPS OF MAMMALS



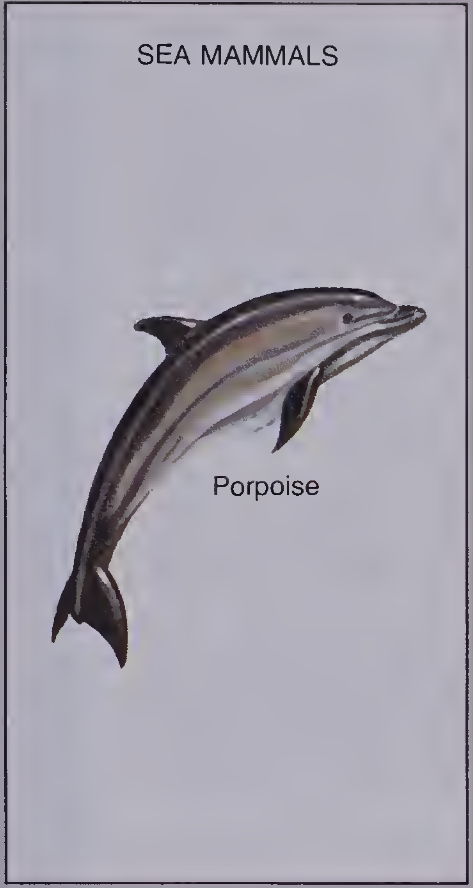
Mammals. All *mammals* have hair. Some mammals such as dogs and cats have hair over most of their bodies. Other mammals such as porpoises and whales have hair only on parts of their bodies.

Nearly all kinds of mammals produce their young alive. They do not lay eggs. The female mammals feed, or *nurse*, their young with milk made in their bodies. No other animals do this.

Mammals are warmblooded. This means that a mammal's body tends to stay warm even if the air or water around it is cold.

Scientists have sorted mammals into smaller groups. The main groups are shown on these two pages.

In each group the members are alike in some ways. The groups differ in other ways. But all are mammals. Why?



SOMETHING TO TRY

Is your body temperature different when you feel cold than when you feel warm? You can test it both ways and find out!

Take your temperature sometime when you feel cold. Take it again when you are sweating from exercise. What do you observe?

Birds. All *birds* have feathers. No other kind of animal has feathers.

Birds are warmblooded, too. A bird's body temperature tends to stay the same, even in cold air or water.

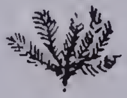
Birds' eggs have hard shells. They are different from the soft-shelled eggs of snakes, turtles, and lizards.

In some ways, the wings of birds are like your arms. The long wing bones are similar to your arm bones. But birds' bones are hollow and light. If they weren't, birds couldn't fly.

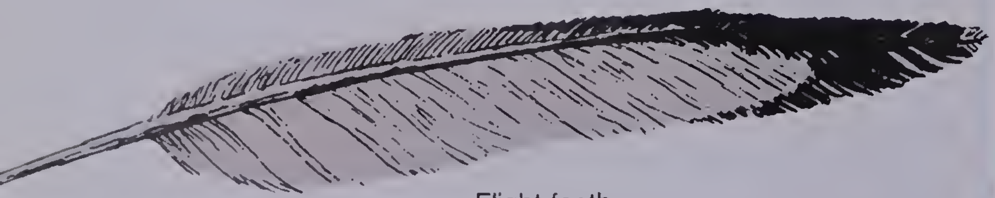
One of the largest bones in a bird is the breastbone. The large muscles needed for flying are fastened to it.

Birds have no teeth for chewing. Their food is ground up after they swallow it. Besides food, birds swallow small stones. These help to grind up the food.

Contour feather

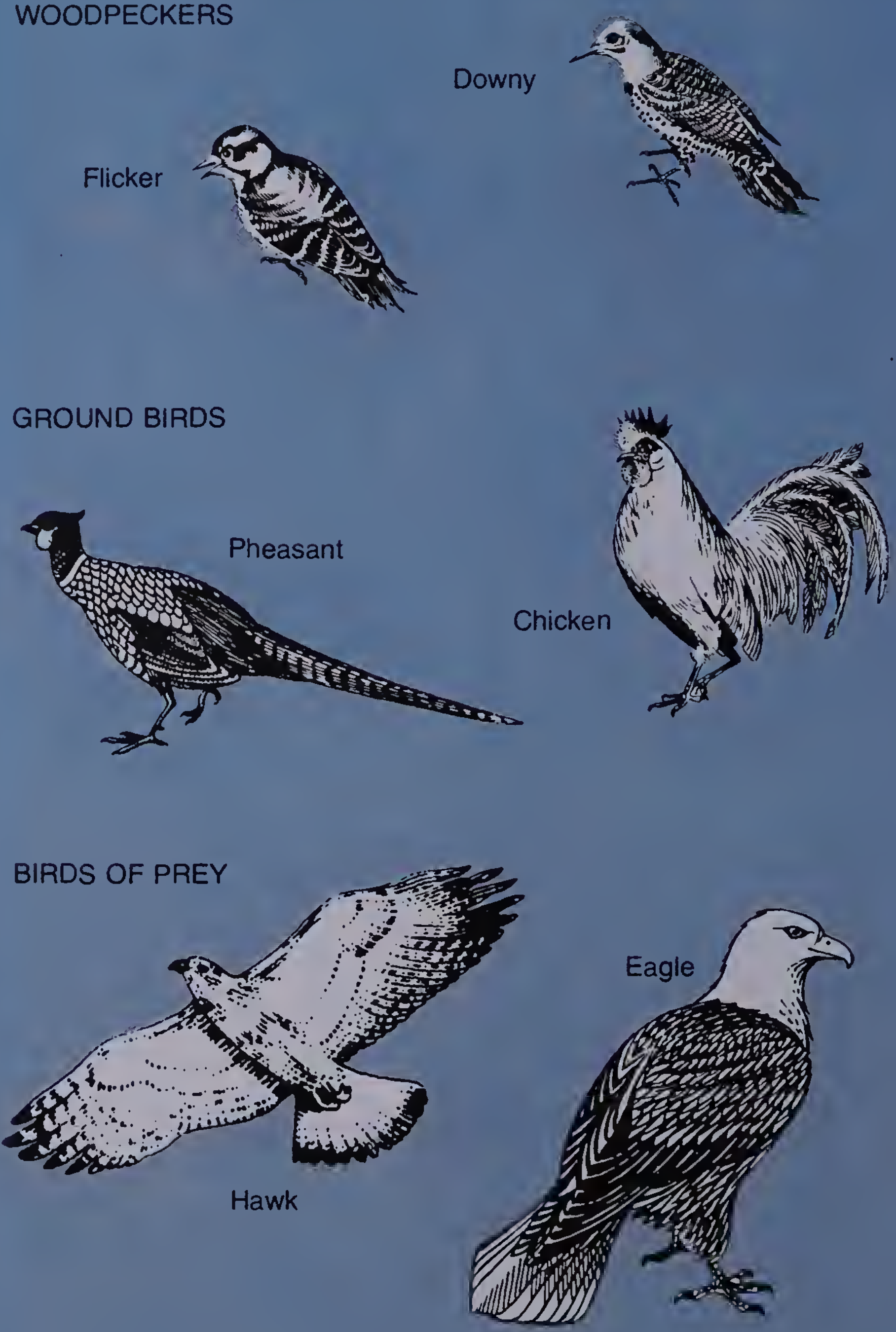


Down feather



Flight feather

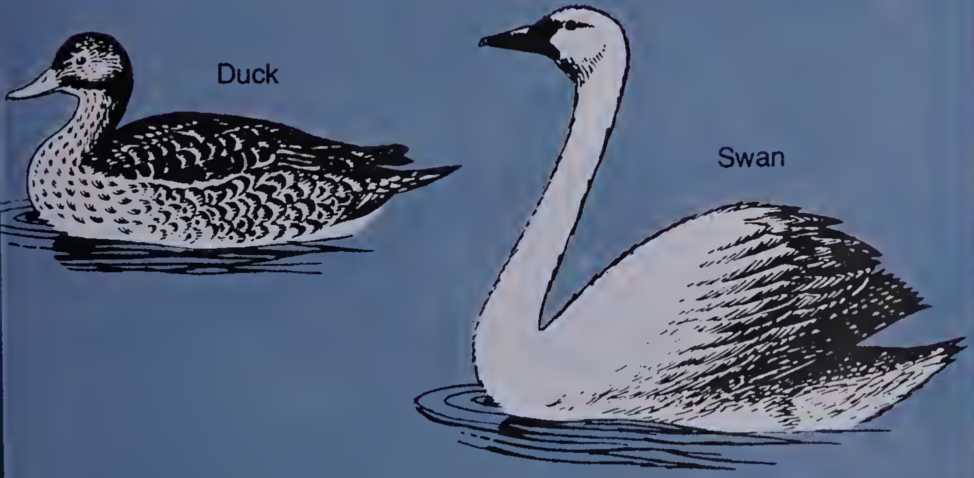
SOME GROUPS OF BIRDS



GULLS

PERCHING BIRDS

WATER BIRDS

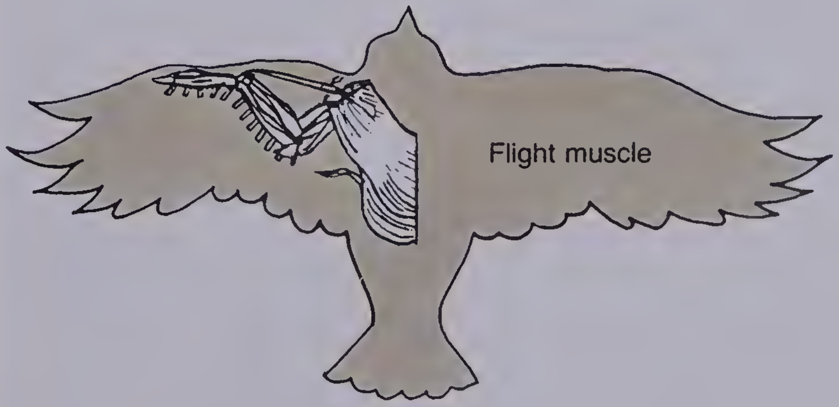


SOMETHING TO TRY

Bend at your waist so your body is parallel to the floor. Hold your right arm out at the side as if it were a wing. Put your left fingers on the muscle of your right chest, where your arm joins your body. Now jerk your right arm downward as if you were flapping a wing. Do it several times. Can you feel the muscle tighten as it moves your arm (wing)?

One end of the muscle is fastened to your breastbone. The other end is fastened to your arm. Tap your breastbone with your fingers. It is too small to hold much muscle. But a bird's breastbone is big for the size of its body. It has a lot of surface which holds the muscle needed for flight. Birds' wings are usually very strong, and their movements are quick.

Look for the breastbone after a chicken dinner. See how much surface it has, and how light and strong it is.



Reptiles. Scientists believe that about 150 million years ago, *reptiles* "ruled" the earth. Among the largest of these reptiles were dinosaurs. Some dinosaurs were more than 15 m long and more than 1000 kg in mass!

Some early reptiles could fly. Others lived in the sea. These giant reptiles died out millions of years ago. Today, most reptiles are less than a metre long, and less than a kilogram in mass.

Reptiles have scaly bodies. They are not warm-blooded. A few are poisonous, but most are harmless. In fact, some make good pets.

Most lizards have tails, and legs with claws. They can climb and move about quickly. This helps them catch insects and other small pests. For this reason, people living in warm climates often like lizards to stay near their homes.

Snakes are similar to lizards in many ways. A snake's skin is dry and scaly. Some snakes lay soft, leathery eggs. Others carry their young inside their bodies until they are born.

But snakes cannot blink their eyes, as many lizards can. Snakes do not have legs, as most lizards do. And snakes almost never eat plant food.

A snake can swallow a small animal whole, without chewing. The reason for this is that a snake's jaws are loosely connected. They can separate and fit around food that is larger than the snake's head.

SOME GROUPS OF REPTILES

LIZARDS

Collared lizard

SNAKES

King snake

TURTLES

Painted turtle

ALLIGATORS AND CROCODILES

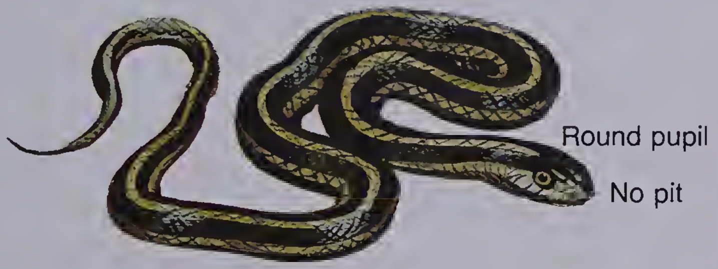
Alligator

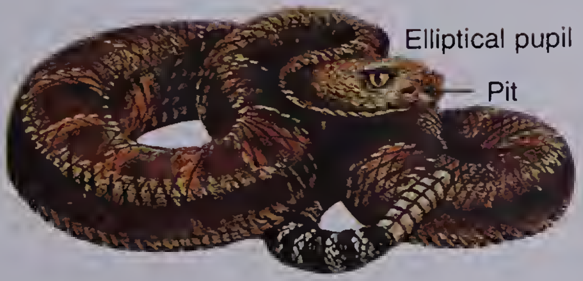
Most snakes feed on mice, insects, and other small animals, many of which are pests. This is one reason snakes should not be killed unless they are dangerous to people.

Turtles have shells, which help to protect them against enemies. Even turtles that live in water must come to the surface to breathe.

Alligators and crocodiles live in warm, swampy places. They feed on fish and small land animals. Once alligators were *endangered* because so many people killed them for their skins. But now they are increasing in number because they are protected by law.

NONPOISONOUS





POISONOUS

SOMETHING TO TRY

Keep a small, harmless snake for a week or so.

Handle your snake gently. Put it in a dry cage. Keep clean paper on the bottom of the cage.

Also, place a dish of water and something rough in the cage. The rough object is for the snake to rub against when shedding its skin.

Feed your snake live insects, worms, or other small animals. If it doesn't eat after a week, let it go where you found it. Be sure to let it go before cold weather. Then it can find a safe place to spend the winter.

Safety Note: *Study these pictures carefully. Be sure that you never handle poisonous snakes! For more details ask your teacher about books you can study.*

Amphibians. The smallest class of vertebrates is *amphibians.* They begin life in fresh water as *larvae* or tadpoles. The larvae have no lungs and cannot breathe air. Instead, they get oxygen through *gills,* or even through their skins.

Some amphibians lose their gills and develop lungs when they become adults. Then they can breathe air.

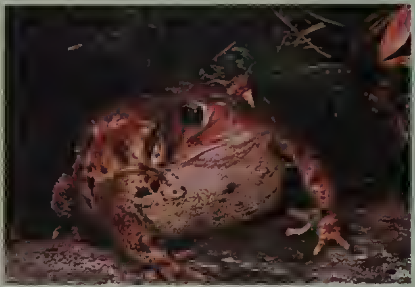
Amphibians can be grouped into two smaller groups. Those adults that have tails are called salamanders. Those adults that don't have tails are called frogs and toads.

Although amphibians live on land, they never get far from water. Even toads, who can live for days in fairly dry places, must seek moisture at times, too.

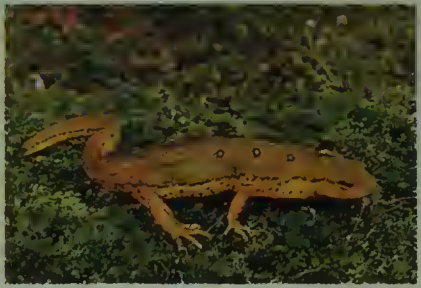
SOME GROUPS OF AMPHIBIANS

FROGS AND TOADS

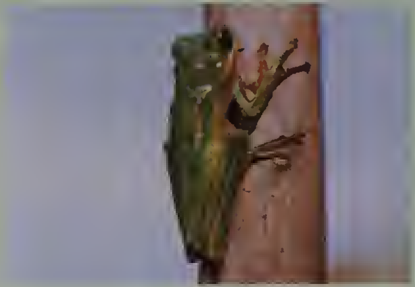
SALAMANDERS



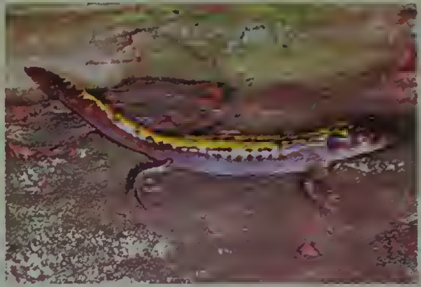
American toad



Newt



Tree frog



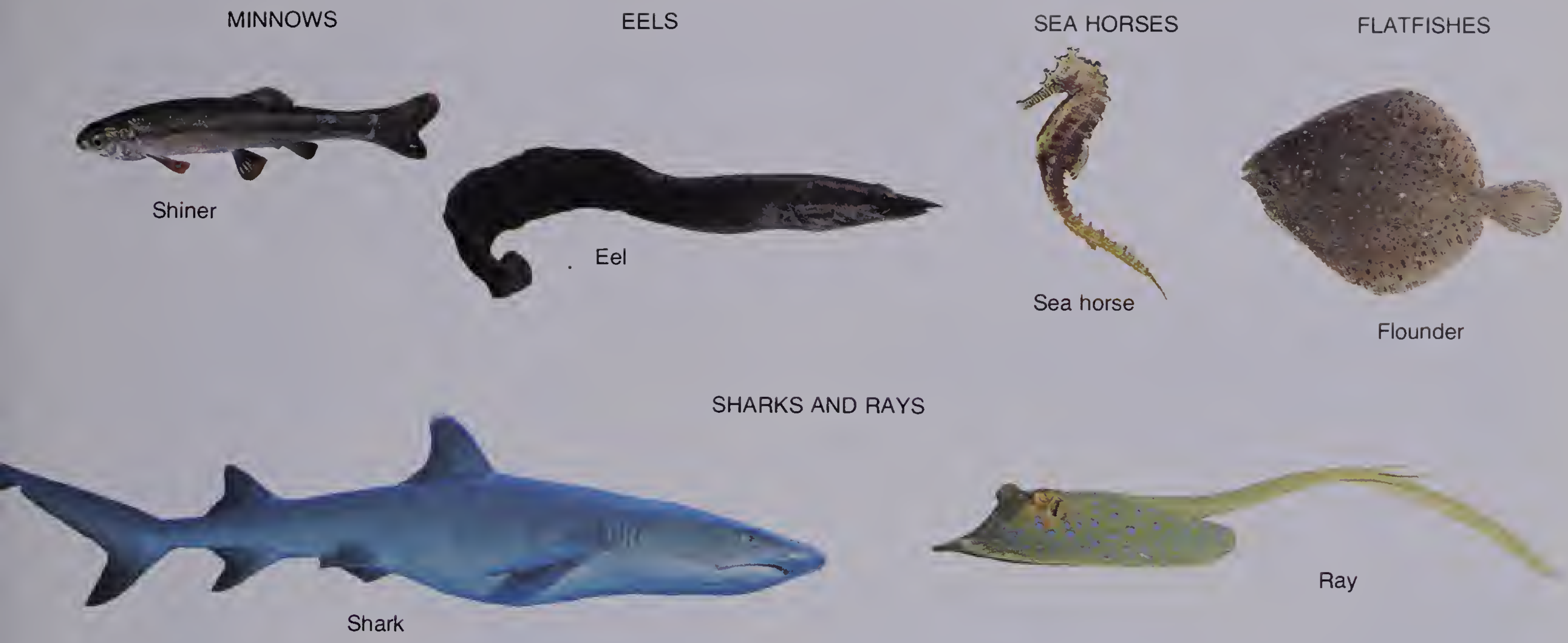
Salamander

SOMETHING TO TRY

Keep a toad for a few weeks.

You will need a terrarium with some moist soil, some low plants, and a water dish. Each day feed the toad some live insects, small worms, or mealworms. Watch how the toad captures and swallows its food. Does it find its food by smell or by sight? What makes you think so?

Here is a puzzler for you. A toad must shed its skin from time to time. What do you think happens to the skin? See if you can find out!


SOME GROUPS OF FISH

Fish. *Fish* are a class of vertebrates that live in water. Most fish have bony skeletons. However, sharks and rays do not. These fish have only cartilage, not bone, in their skeletons.

To "breathe," fish take water into their mouths and force it out past their gills. The gills of fish lie under *gill covers.* You can see them on a freshly caught fish. They are like pink flaps in which blood flows. When water moves past the gills, oxygen passes from the water into the blood.

Most fish have scales, but some do not. Most fish lay eggs, but some, such as guppies and mollies, produce their young alive. Guppies are easy to keep in an aquarium. If you keep them long enough, you may see baby guppies being born.

Most fish look like fish, but some do not! Sea horses and eels do not look like fish. But, like most other fish, they have gills and fins.

SOMETHING TO TRY

Divide some aquarium water into two equal parts. Cool one part to about 10°C. Warm the other to about 30°C. Put a small goldfish into the cool water. Wait a few minutes. Then count how many times its gill covers open and close in one minute.

Next, put the fish into the warm water. Wait awhile. Then count how many times its gill covers open and close in one minute.

How do the two counts compare? From which water does the fish seem to get oxygen more easily?

Animals without backbones. *Invertebrates* are animals without backbones or bony skeletons. Some invertebrates, such as crabs, spiders, and insects, have a hard covering on their bodies.

But invertebrates do not have any bones. Many invertebrates don't even have hard coverings. Their bodies are soft, inside and out. Some common invertebrates are shown below.

Clam

Earthworm

Crayfish

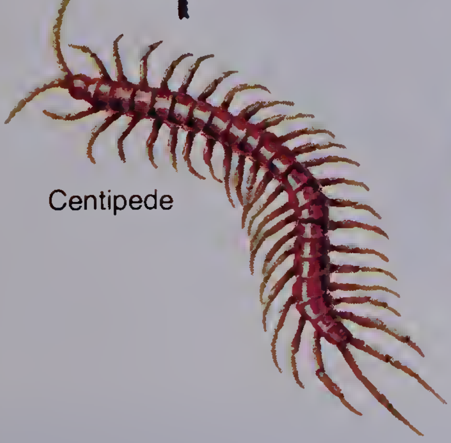
Sea star

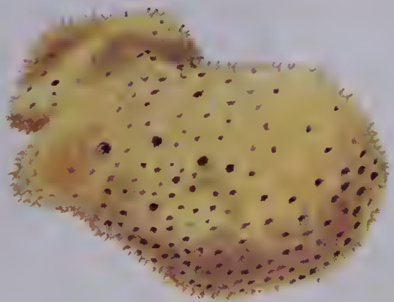
Housefly

Butterfly

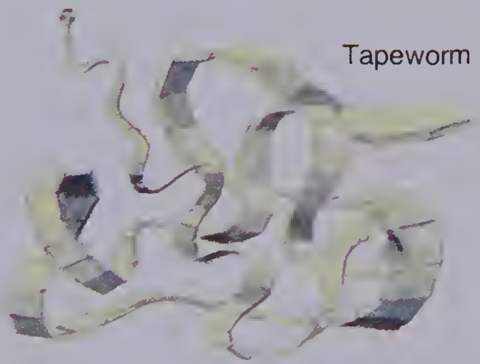
Spider

Slug


Centipede


Sponge

Sea anemone


Tapeworm

Fly

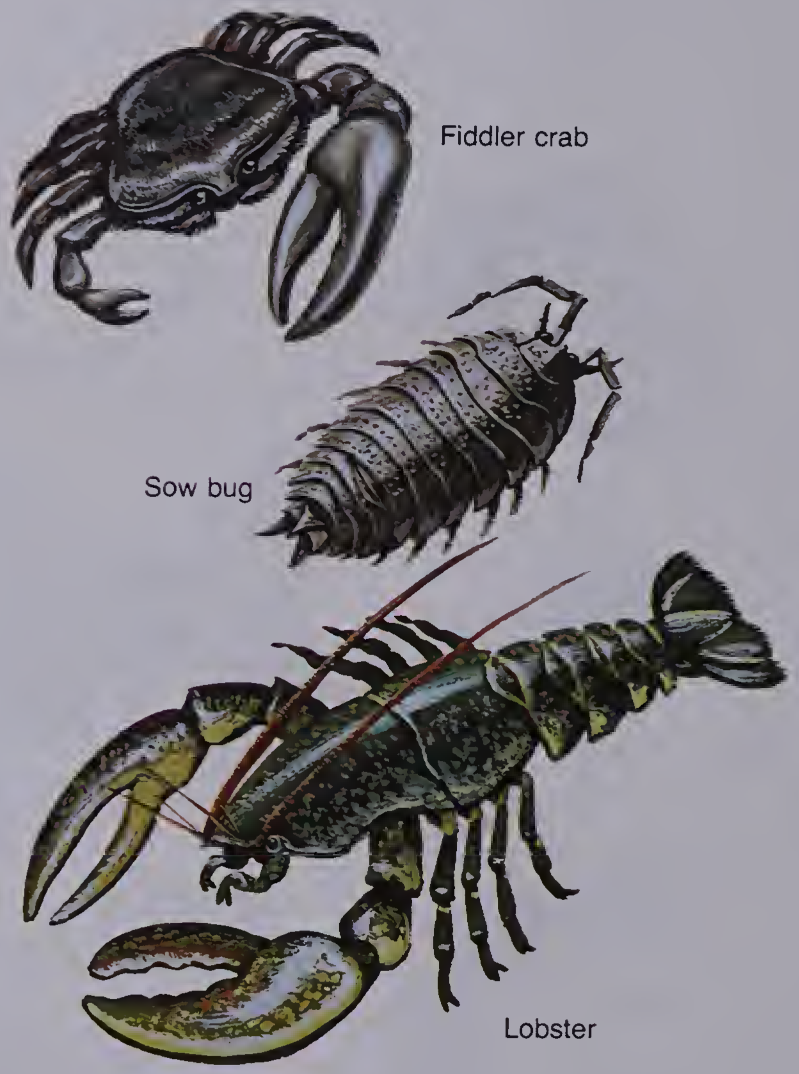
Beetle

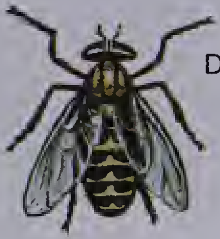
Arthropods. Look closely at the legs of this beetle and fly. They are like stiff tubes. One "tube" is connected to the next, at a *joint*. The legs are something like pieces of drinking straw strung together on a thread. The tubes are stiff, but they move at the joints.

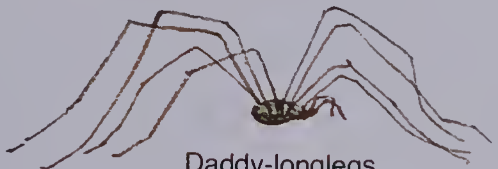
The beetle's leg and the fly's leg are like the legs of many other invertebrate animals. Invertebrates with jointed legs are called *arthropods*. "Arthro" means joint. "Pod" means leg. The animals on these pages are arthropods. Notice that they have jointed legs. Are they alike in other ways? How do they differ?

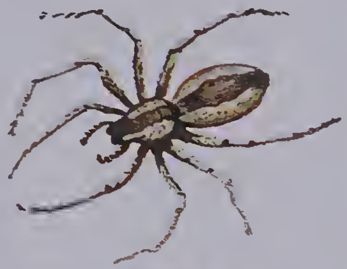
Your legs have joints, too. But they are not like those of an arthropod. How do they differ?

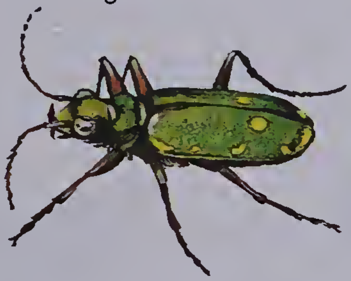
ARTHROPODS

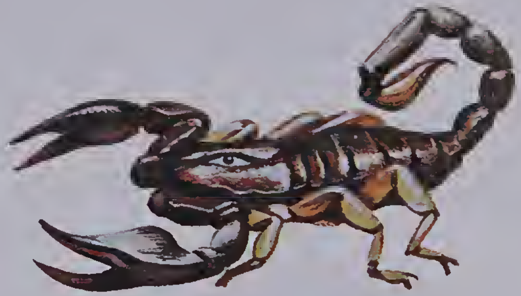


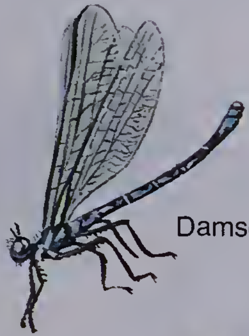

Deer fly

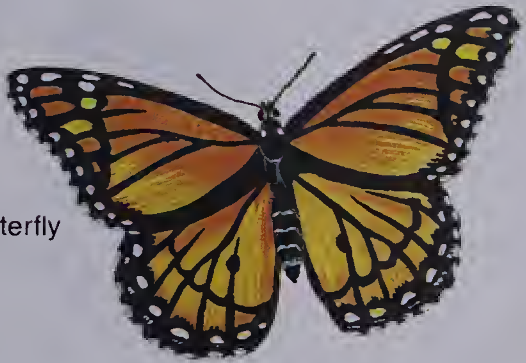

Daddy-longlegs


Funnel-web spider


Tiger beetle


Scorpion


Damselfly


Monarch butterfly

SOMETHING TO THINK ABOUT

How would you sort these arthropods into three groups? Those that live in water as adults need gills. Could those animals with gills make up one group? Could the number of legs be used in grouping? Could you put animals with wings in one group, and those without wings in another group?

Scientists have found that appearance isn't always the best clue to sorting. Think of the best way to sort these animals. Then compare your groups with those of a classmate. How well do you agree?

Insects—arthropods with six legs. Suppose you counted the legs on a lot of arthropods. Most would have six legs. Do you know what six-legged arthropods are called? They are *insects*.

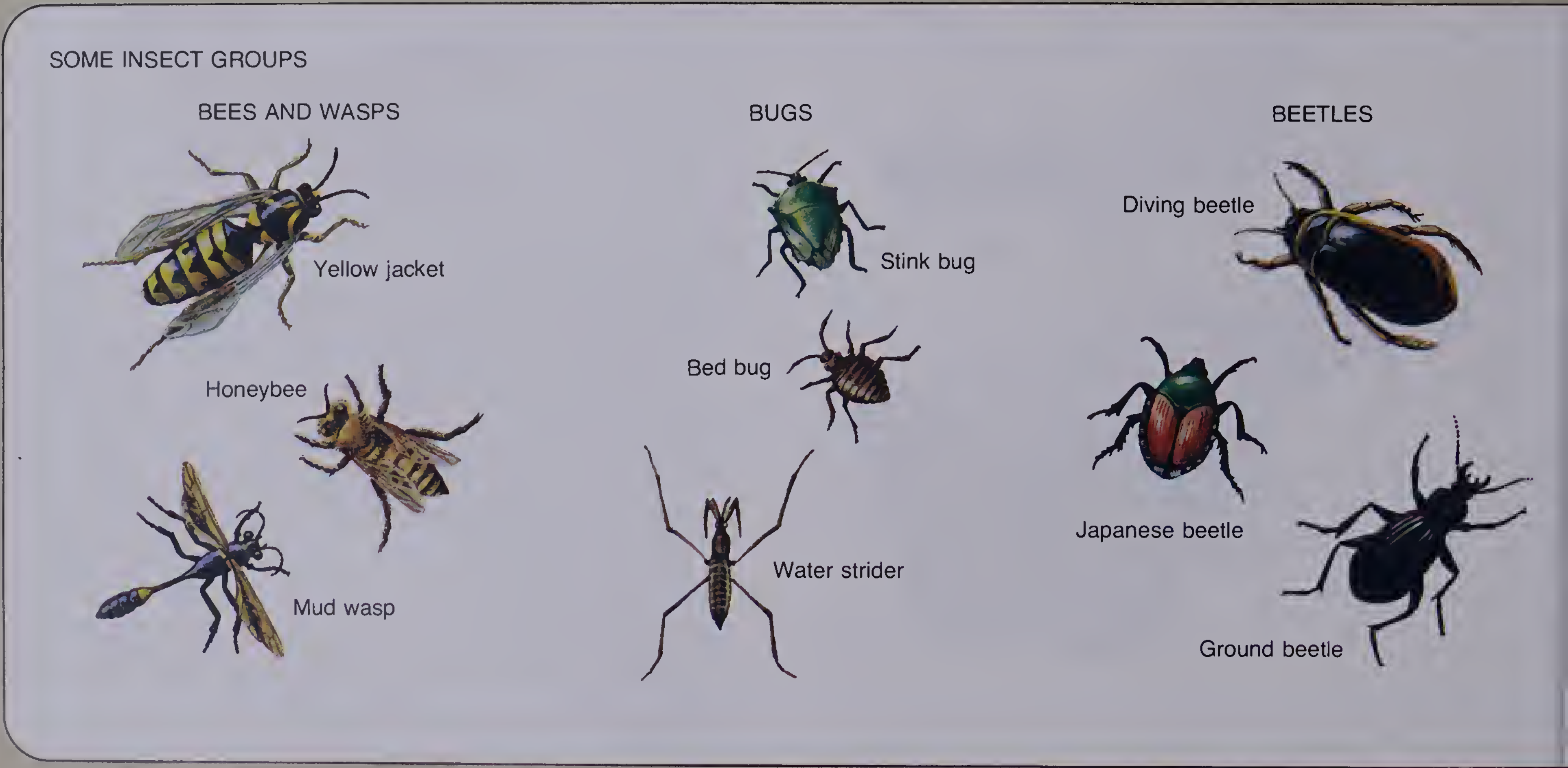
Insects are the largest group of arthropods. In fact, they are the largest group of all animals. There are more kinds of insects than of all other animals together!

This huge group called insects has been sorted into several smaller groups.

Some of the groups are shown on these pages. The members of each smaller group are alike in some way. See if you can find out how.

Bees and wasps have four thin, clear wings. It is only the females of this group that can sting. The males cannot.

Bugs have beaks. They suck juices from plants and other animals. Their wings overlap in back to form a sort of triangle. You can tell bugs from beetles by their wings and their beaks.



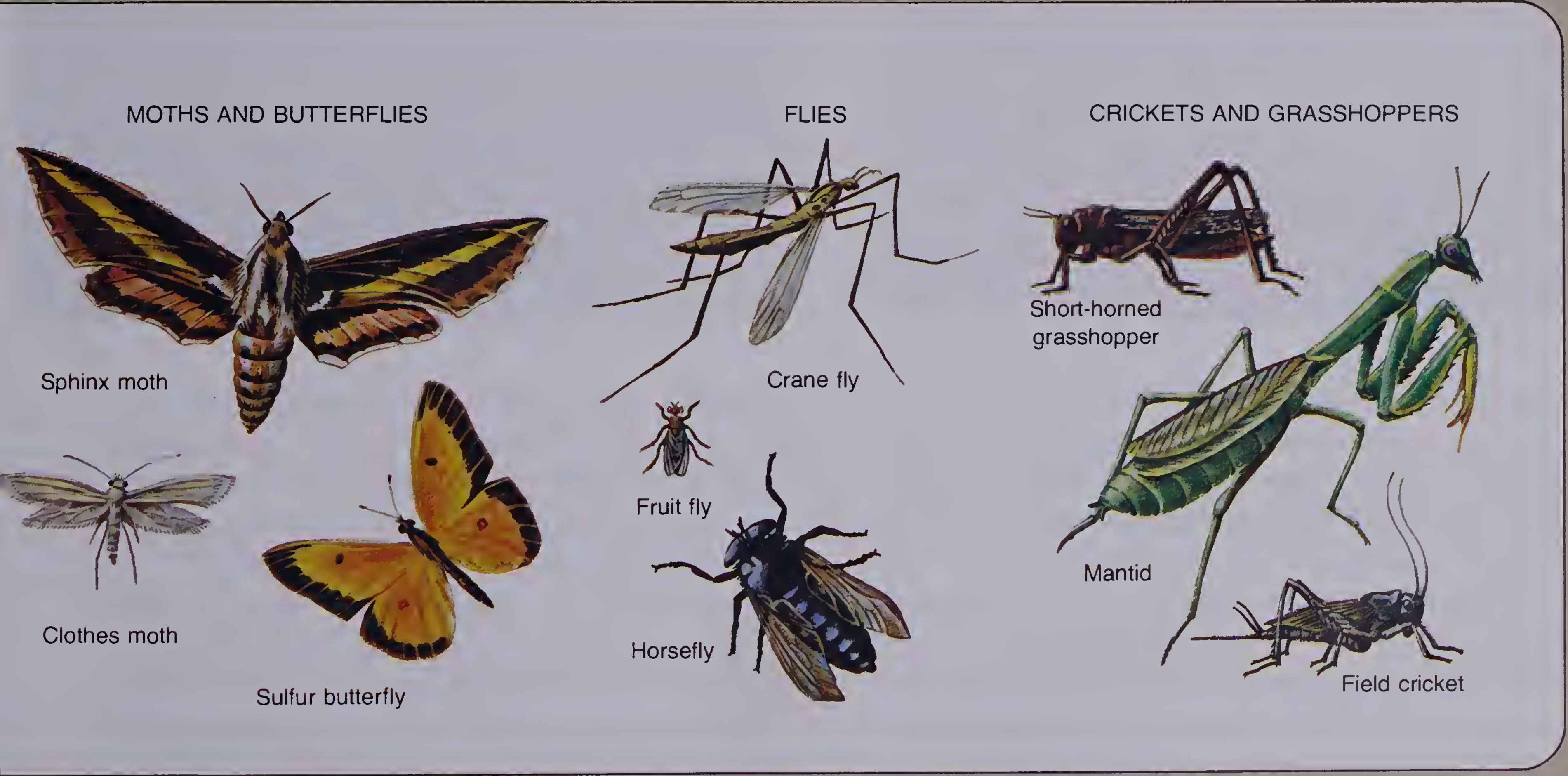
Beetles have hard stiff outer wings or wing covers. These help to protect the underwings, used for flying. Beetles do not have beaks. They chew their food. Beetles can sometimes pinch with their jaws. But they cannot sting.

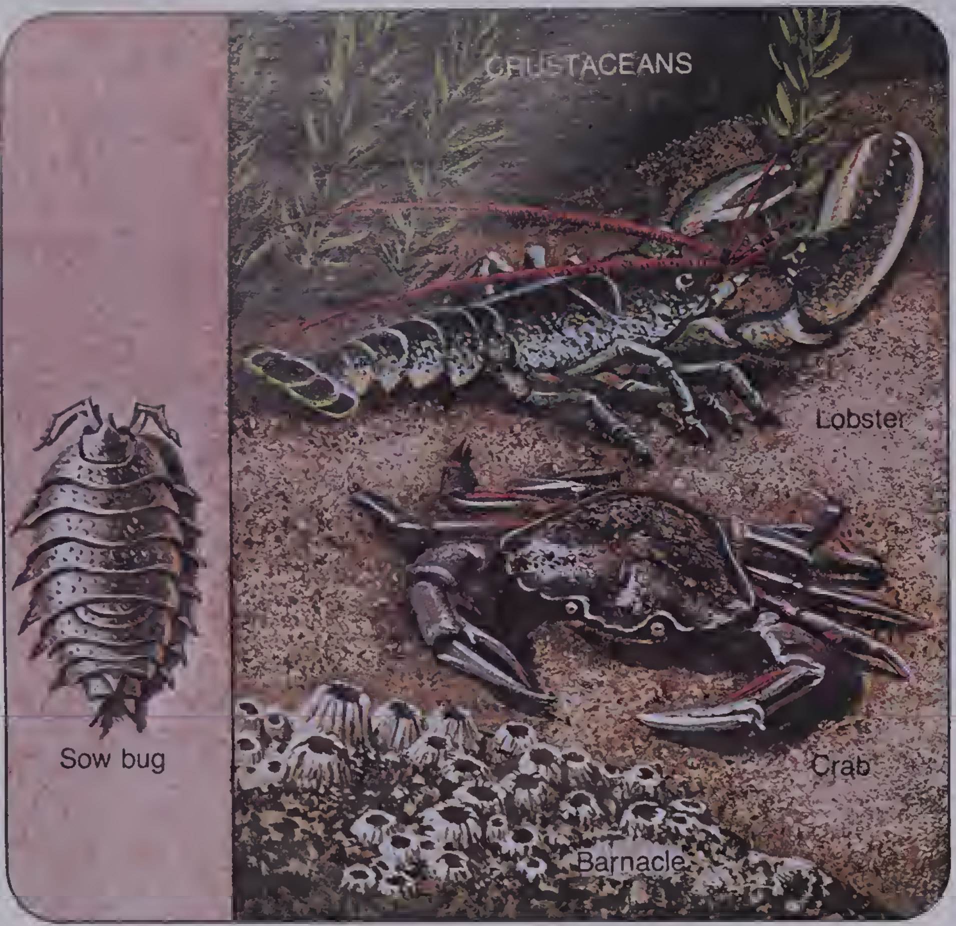
Moths and butterflies have wings covered with tiny scales. You can see them with a magnifying glass. It is the scales that give some moths and butterflies their beautiful colors. Caterpillars are the larvae of moths and butterflies.

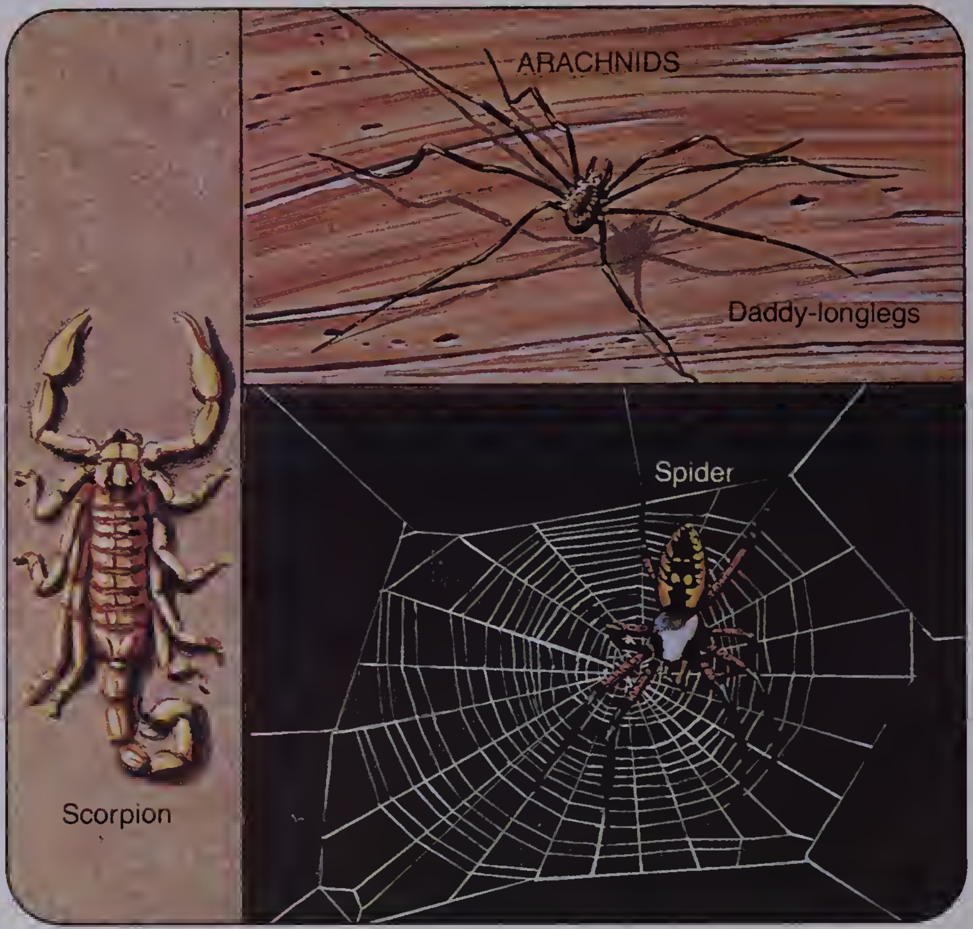
Flies have only two wings. Behind these are two little knobs on stalks. Long ago, they might have been wings, too.

The front wings of crickets and grasshoppers are leathery. They protect the soft, folded flying wings behind them. Most of this group have hind legs made for jumping.

Some crickets and grasshoppers can sing. On a warm autumn night, try to locate one with your flashlight. How is the singing done?





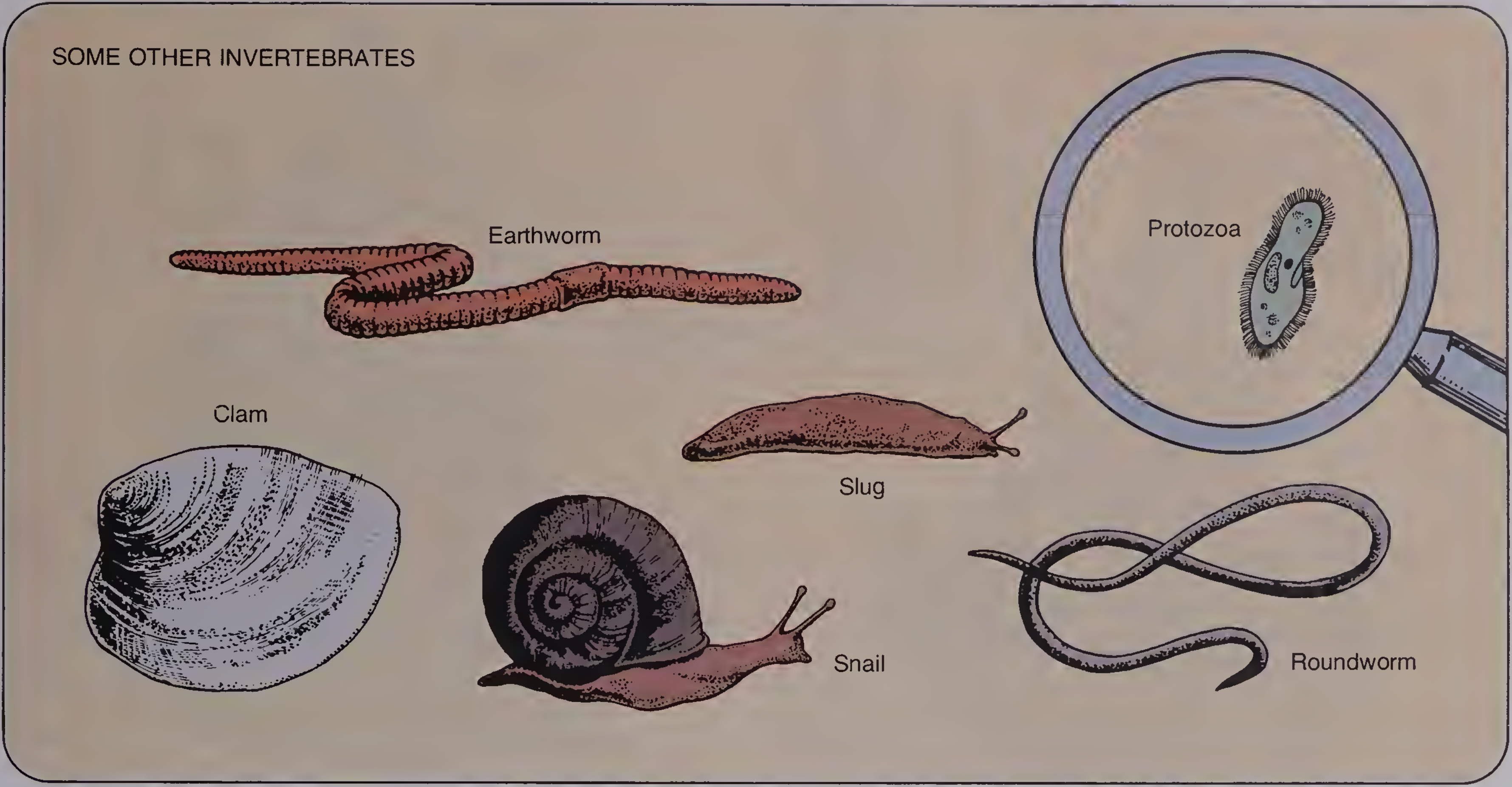


Other arthropods. Crabs, lobsters, shrimps, and barnacles are *crustaceans.* They have a hard covering, more than six jointed legs, and gills. Their gills help them get oxygen from the water in which they live.

A few crustaceans, like the sow bug, live on land. But because they have gills, they must stay where it is damp. So you often find them under wet leaves or boards. Look for some outside your house and study them.

Spiders, scorpions, and daddy-longlegs are *arachnids.* They don't have gills as crustaceans do. Instead, they have "book-lungs," which are something like pages in a tiny book. These take oxygen from the air.

Arachnids have eight walking legs and live mostly on land. They eat smaller animals which some catch in their webs, and others by running after them. Even though their jaws have poison glands, arachnids almost never hurt people.



Some other invertebrates. Many invertebrates do not have jointed legs. Some have neither hard coverings nor legs. Earthworms, for example, have soft bodies and no legs.

Clams and snails are similar in body structure. They have hard covers but no legs. Slugs are like snails without shells.

Many small invertebrates live in water. Some, called *protozoa,* are so small that you need a microscope to see them. "Proto" means first. "Zoa" means animals. Protozoa were probably the first animals on earth.

Some invertebrate animals, such as certain worms, live inside other animals. The worms that live inside dogs and cats have no mouths. Instead, they take their food right through their skin—from what dogs and cats have already digested.

There are so many kinds of invertebrate animals! And such interesting ones!

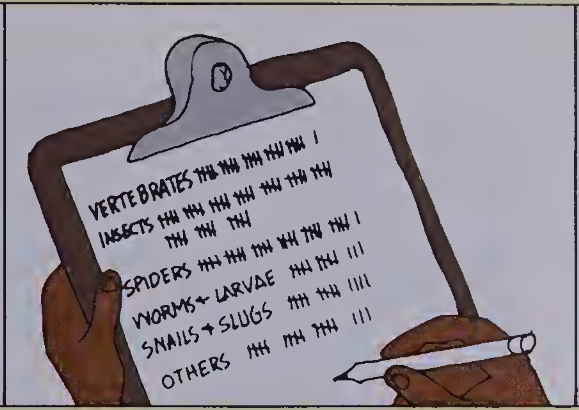
More vertebrates, or invertebrates? Some vertebrate animals are huge. Elephants, whales, and giant bears, are among the biggest vertebrates on earth. Even the smallest vertebrate is big enough to see without a magnifying glass.

Most invertebrates are much, much smaller than vertebrates. Most kinds are smaller than a housefly. You need a microscope to see some.

Suppose that you put all whales, elephants, people, and other vertebrates on one side of a very large balance. And you put all worms, insects, and other invertebrates on the other side. Which side do you think would have the greater mass?

The invertebrate side would have the greater mass. There are more invertebrates than vertebrates. And there are many more kinds.

OBSERVE



RECORD

CLASSIFY

COMPARE

SOMETHING TO TRY

Take an animal count, or *census*. Your class may wish to do this by committees. Each committee can investigate a different place. One group might choose a vacant lot, one a lawn, one a shrubby place, and one a woods.

First record the number of vertebrates you find in the area. Include people, dogs, birds, lizards, and any other vertebrates that you see.

Then, with pencil and paper, flashlight, magnifying glass, and trowel, begin to hunt for invertebrates.

Do not handle the animals that you find. Just list them. One way is to write down all the groups you can think of. Add a group labelled "Other." Each time you see an invertebrate make a mark next to the group in which it belongs.

Search on the outside of buildings, and under windowsills. Look along the bottoms of old brick walls. Look under tree bark, under stones, and beneath pieces of cardboard, too. Examine bushes, leaves, and even old bird nests. Look carefully.

Examine one square metre of soil surface. With your magnifying glass search among the grass and leaves. Dig down at some places to see what is in the soil. Look wherever you think a small animal could hide.

When you have finished the census, add up all the invertebrates you found. How does this compare with the number of vertebrates?

Actually, you probably saw only a small part of the invertebrates around you. This is because you could not examine all the places where invertebrates live. Think how many more there must be in a large field! Or a forest! Or the sea!

Plant Groups LESSON 5

Green plants with seeds. Like animals, plants can also be sorted into two large groups. In one group are plants that produce seeds. In the other group are plants that do not.

Seed plants can be sorted into two smaller groups—*cone-bearing* and *flowering*.

Seeds from cones. Pine and spruce trees are examples of cone-bearing plants. The seeds grow in cones. Many of these trees are called *evergreens* because they have leaves (needles) all year.

Seeds from flowers. Most seeds, however, come from flowers. Some flowers are large and colorful. But others are small and hard to see. Some don't look like flowers at all.

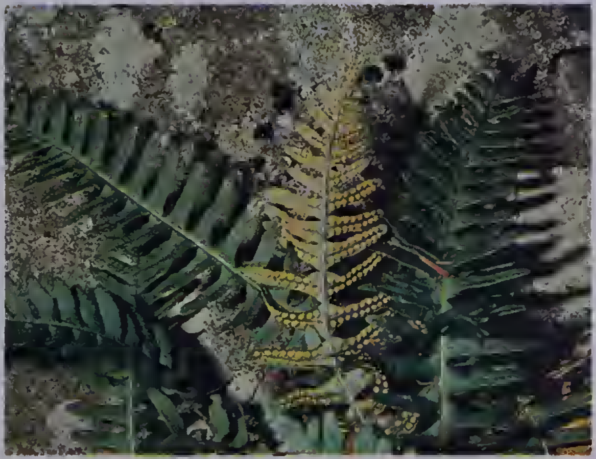
What flowering plants can you name that have large, colorful flowers? What are some that have very small flowers?

SEED-PRODUCING PLANTS

CONE-BEARING

FLOWERING

Mosses



Ferns

Seaweed

Green plants without seeds. Many plants do not produce seeds at all. Among them are ferns, mosses, molds, mushrooms, and seaweeds. Some of these are green, and may look like seed plants. But they do not have flowers or cones. So, they cannot produce seeds. Instead, they produce new plants from *spores*.

If you look closely at the underside of a fern *frond,* or leaf, you may find some small brown dots. Spores come from these dots. The spores are so tiny that they seem like fine dust. Each spore might grow into a new plant, as a seed does. They are not as big as seeds. They do not come from flowers. Yet, new plants can grow from them.

One plant may produce millions of spores. They are less likely to grow than seeds. But, there are so many spores that some are sure to grow.

Nongreen plants without seeds. *Fungi* are another group of plants without seeds. Like ferns, they produce spores. Most fungi are white, brown, or gray. They live in the soil, or inside fallen trees and dead animals.

Plants that have *chlorophyll* (the green matter in leaves) make their own food. They make it from water and carbon dioxide, with the help of sunlight. Later, the food these plants make becomes food for animals. But fungi cannot make their own food. Instead, they feed on other organisms, or on things that once lived.

When living things die, their chemicals must be *recycled,* or returned to the soil, water, and air. If this did not happen, other organisms could not get what they need to live. By causing *decay,* fungi help to recycle needed chemicals.

Some fungi can be eaten. Mushrooms are fungi. But some kinds, such as *Amanita,* are deadly poisonous. You should never eat a mushroom unless you know it is safe.

Some molds cause food to spoil or decay. This happens when spores land on the food and grow. But if the food is kept cold or dry, then mold spores cannot grow easily.

Why do you think food keeps well in a refrigerator? Why do you think fruit that is left out often spoils? Why do you think crackers do not spoil as easily?

Amanita mushroom

EXPERIMENT

Get a few samples of food and some plastic bags. Put one different food into each bag. Also, get a piece of cardboard, a piece of wood, and a stone. Put one of these items into each plastic bag. Add 10 drops of water to each bag. Seal the bags with rubber bands. Set them in a warm, dark place.

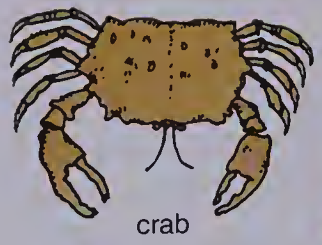
After three days, look at what is inside, without opening the bags. What changes do you see in each of the foods and other materials?

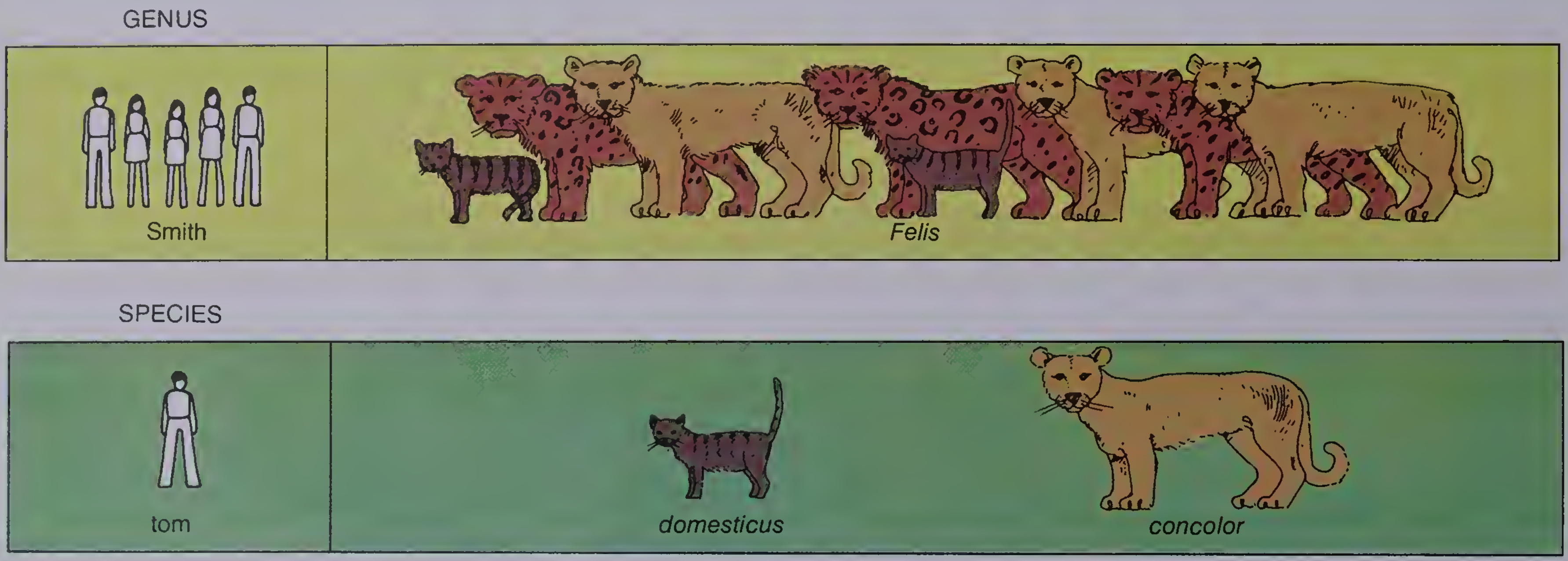
Put the bags back and wait three more days. Then what changes do you see? Which materials changed the most? Which show no change? Be sure to use your magnifying glass to help you look closely.

From your observations, what kinds of materials do you think fungi and other molds grow on? Where do you think the spores came from that started these fungi? What do you think will happen to your fungi or molds after two weeks have passed? Put them back and see!

Naming Organisms LESSON 6

There are thousands of different kinds of organisms. It is important for scientists to be able to talk about them. Suppose living things had only common names. Then the name "crab" could mean any of three different organisms. Talking about them would be difficult. One scientist might not know what another one meant.





Scientific names. Scientists have developed a better system for naming organisms. Each organism is given a *genus* name and a *species* name. Kinds of organisms that are similar in many ways are grouped in one genus. Horses and zebras are in the same genus. But they are not identical. So horses and zebras are in different species.

In a scientific name, the genus name comes first, beginning with a capital letter. It is something like your last name, or family name. There may be many people with your family name. Likewise, there may be many kinds of organisms with the same genus name.

You have a first name to tell you from others in your family. Likewise, each kind of organism in a genus has something like your first name. It is the species name. Species names usually are not capitalized.

The scientific name for "house cat" is *Felis domesticus*. *Felis* is its genus name; *domesticus* is its species name. No other organism except the house cat has this name. *Felis domesticus* means house cat in Japan, Canada, Mexico, and all over the world. Can you see how having standard names for organisms makes it much easier to talk about them?

Building scientific names. Scientific names often have parts that come from Greek or Latin words. Here are some commonly-used parts and their meanings:

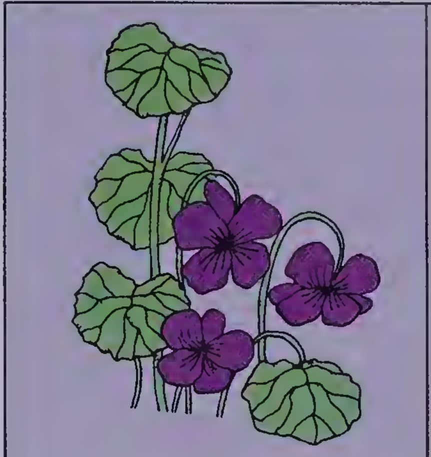
micro-	means small	*poly-*	means many
macro-	means large	*-phyllum*	means leaf
uni-	means one	*-flora*	means flowers

What species name would you give to each of the following:

- an *Aster* that has many leaves?
- a violet *(Viola)* that has only one flower?
- a plant of the genus *Aster* that has large flowers?
- a *Geranium* that has small leaves?

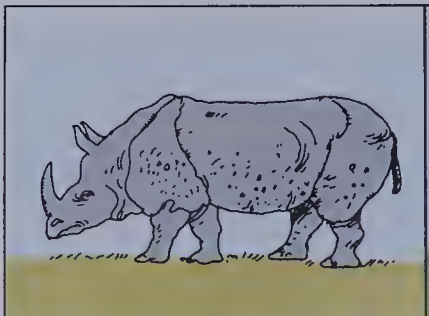
SOME NAMES TO THINK ABOUT

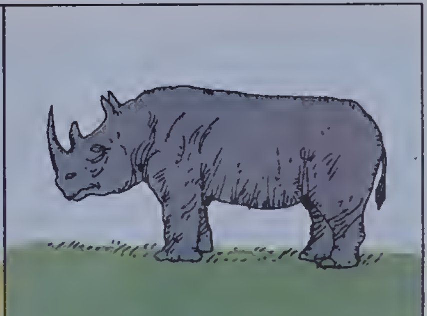
1. Sometimes a species name tells where scientists first saw the organism. In the two examples below, where do you think the species was found?


Viola canadensis

Lepus californicus

2. Sometimes a species name describes the appearance of an organism. One of the two animals below lives in Africa and one in India. Their species names tell how they differ in appearance. What do you think each species name means?


Rhinoceros unicornis


Rhinoceros bicornis

Ideas for REVIEW

- By knowing something about one member of a group, you may know something useful about other members of that same group.
- The members of each group of organisms are alike in certain ways.
- Each group differs from all other groups in certain ways.

- Animals can be sorted into two main groups: those with a backbone, and those without.
- An animal that has a backbone is called a vertebrate.
- Vertebrates can be sorted into five main classes: mammals, birds, reptiles, amphibians, and fish.
- An animal that does not have a backbone is called an invertebrate.
- Arthropods make up the largest class of invertebrates.
- Insects form the largest group of arthropods. There are more kinds of insects than kinds of all other animals.
- Plants can be sorted into two main groups: those that produce seeds, and those that do not produce seeds.
- Some plants that do not produce seeds are ferns, mosses, molds, mushrooms, and seaweed.
- Most plants produce far more seeds and spores than can grow.
- In order to talk about organisms, scientists have given all known organisms special scientific names.
- All scientific names are made up of a genus and species name.

TEST Your Understanding

A. Choose a word from column B that best matches the words in column A. On a piece of paper, write the letter of the word next to the number it matches. *Do not write in this book.*

A

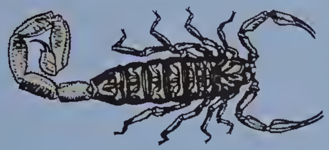
1. warmblooded, have hair
2. most have scales, breathe with gills
3. warmblooded, but no hair
4. scaly bodies, leathery eggs
5. jointed legs
6. can't see them without a microscope
7. no scales, young have gills

B

a. amphibians
b. arthropods
c. birds
d. mammals
e. fish
f. reptiles
g. protozoa

B. On your paper, write the answer to each of the following questions.

8. To what very large group of animals do you think this belongs?



9. What makes you think so?

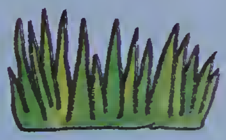
C. Write the numbers 10 to 15 on your paper. For each one, tell whether the organism shown to the right produces seeds or spores. Do this by writing the word "seeds" or "spores" on your paper.

10. Rose

11. Fern

12. Mushroom

13. Spruce tree

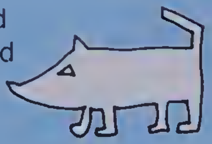


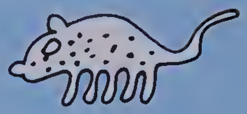
14. Grass

15. Moss

PROBLEMS

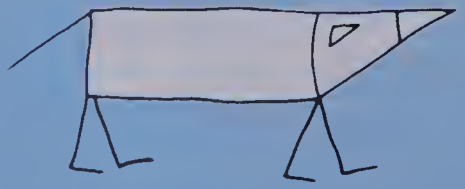
GLERTS	SQUAFFLES
Triangular heads	Rounded heads
Bodies with straight sides	Bodies with curved sides
Tails angled	Tails curved or "snaky"
Four feet	More or fewer than four feet
Ears pointed	Ears rounded
Nose pointed	Nose rounded
Body plain	Body dotted





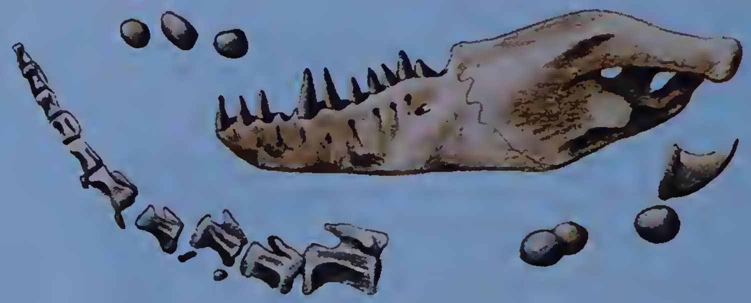
1. Above are two kinds of make-believe animals—glerts and squaffles. Study them.

Is the animal below a glert or a squaffle? What makes you think so?



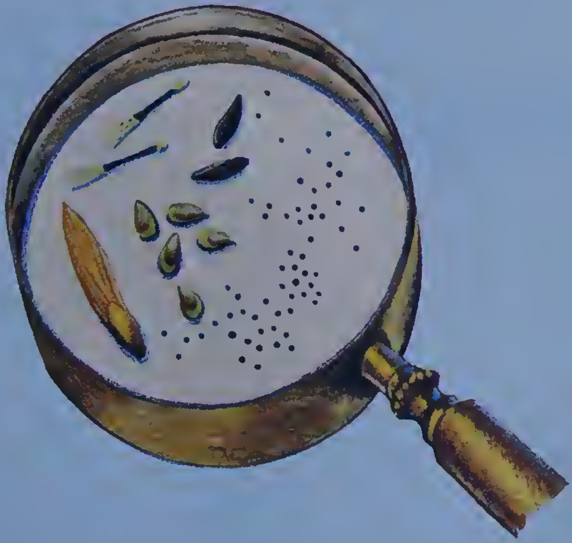
2. Suppose you came upon these objects, all lying close together in the soil:

- smooth, round stones about golf-ball size
- stony vertebrae that seem to be from a tail
- a stony jawbone almost a metre long
- a stony claw about 10 cm long



What might you infer about the animal these came from? About how big do you think it was? Why do you think there were stones like these among the bones?

3. These things can be sorted into two groups. What are the groups? In what ways are they alike? In what ways are they different? Where is the nearest place you could find at least one from each group?



FIND OUT on Your Own

What does "warmblooded" mean?

After you have been outdoors in the cold air, take your temperature. Do this by putting an oral thermometer under your tongue. Record this number. (Be sure to sterilize the thermometer in alcohol afterward.)

Now use an ordinary thermometer and some cotton to measure the temperature at these other places.

- your palm
- your forehead
- your foot
- your elbow
- your knee
- your armpit

Record these numbers.

Why is the cotton needed?

What part of your body is the hottest? What part is the coldest? What part of your body stays at the most nearly constant temperature? How could you find out?

2 Rocks in Layers

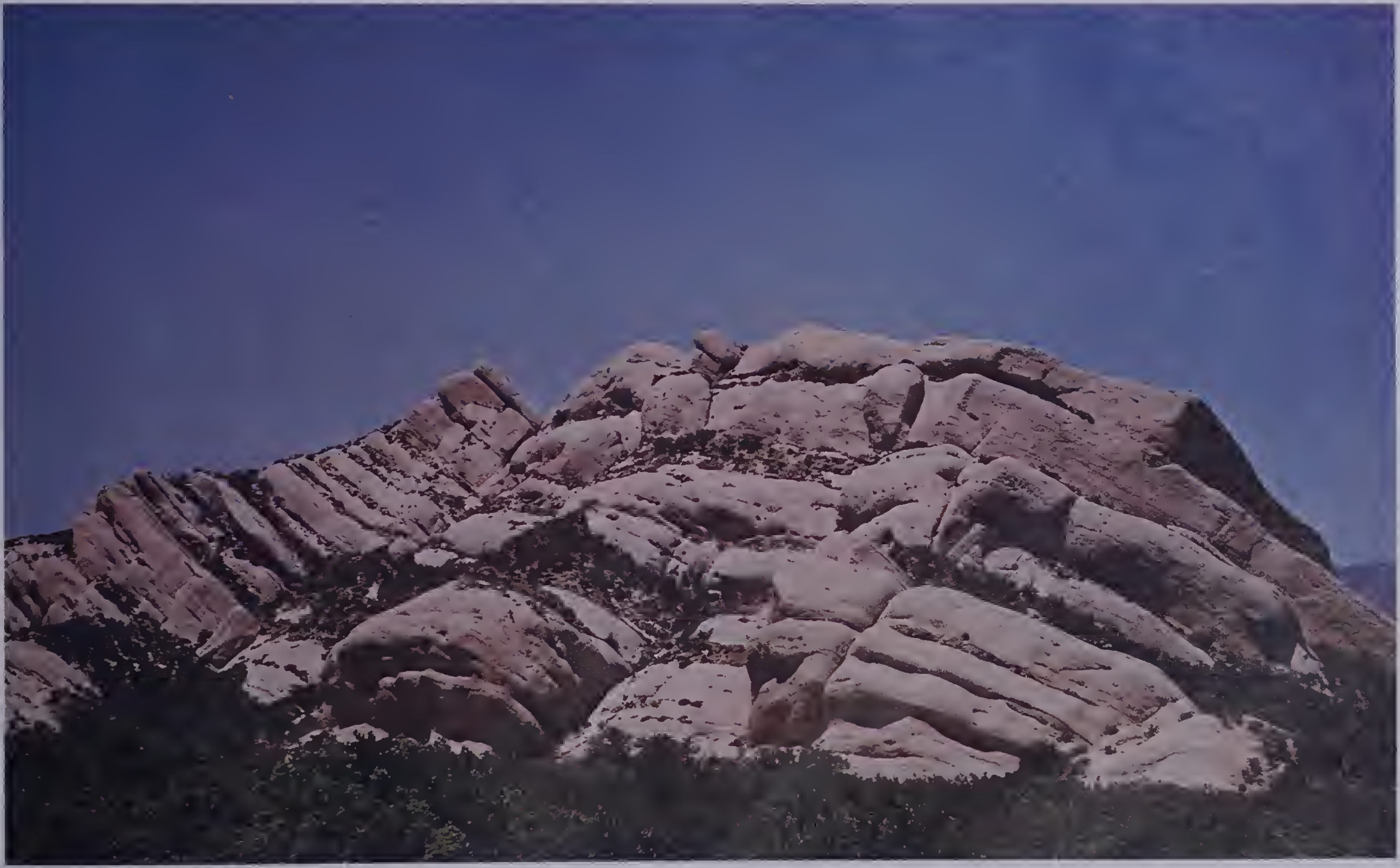
In some places you can see rock sticking out of the ground. Sometimes it is only a big piece of rock. At other times, it is not a separate piece. Instead, it is part of the *bedrock* of the earth.

Have you ever seen bedrock? There is bedrock in the ground wherever you go. But mostly it is covered over and hidden. Only in some places does it stick out. What are some of these places?

The pictures on these pages were taken at two different places. They show bedrock sticking out of the ground. In one place the bedrock is in layers. In the other it is not in layers. Can you see the difference?

Why might bedrock in some places be in layers? How might these layers have formed?

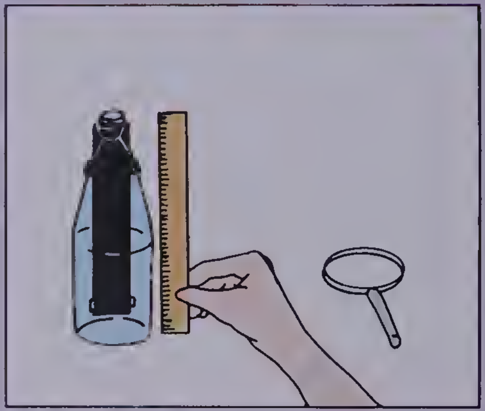
Think of some other things that are in layers. Think of cake, of wood, and of paint. How were the layers in these things formed?

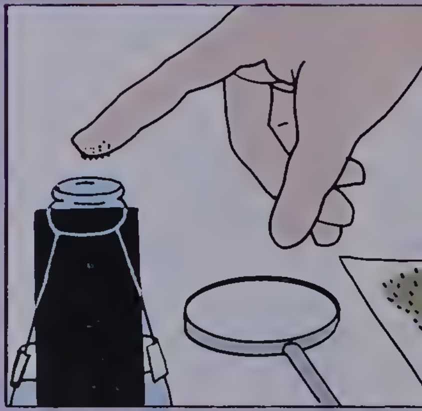


Settling of Rock Particles LESSON 1

Bedrock sticks out in cliffs, in canyons, and on some mountaintops. But in most places you have to dig down to get to it. In some places it is hundreds of metres down.

Nearly everywhere, bedrock has loose pieces of rock on top of it. These may be boulders and pebbles, as well as smaller pieces. Some of the smallest particles of rock are sand grains. But there are even smaller rock particles in mud.





SOMETHING TO TRY

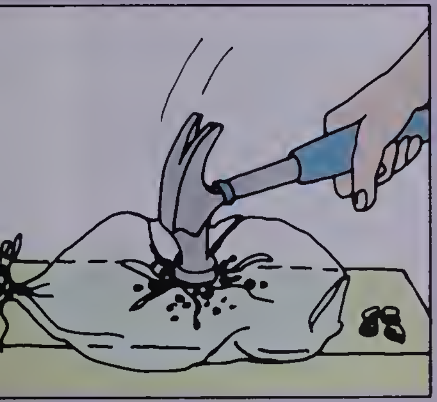
Did you ever hold a sinking sand race? Try doing this one with two or three of your classmates.

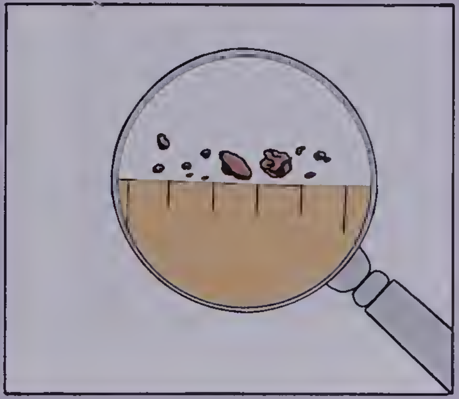
First find a tall bottle—the taller the better. It should be at least 30 cm high. Tape a wide strip of black paper to the outside. It will be easier for you to see the sinking particles against this dark background.

Then set the bottle where it gets good light, at eye level. Fill it to the very top with water.

Now drop a pinch of clean sand into the water. Watch the grains as they sink. Do they all fall at the same speed? If not, which ones sink faster? Check your observations with your classmates.

If you wet the top of your finger, sand grains will stick to it. Then, when you dip it into water, they will come off. They will all come off at the same time. None will get a head start. The race must be fair.





In this way you can compare how fast different kinds of sand sink in water. You can test

- fine, medium, and coarse sand
- seashore, creek-bed, and sand-dune sand
- sandbox sand and builder's sand

You also can make some sand by breaking up a small piece of rock in a plastic bag. You might even write to other places for samples of sand.

SOME OTHER THINGS TO TRY

Which do you predict would win a sinking race, mud particles or sand grains? Test your prediction.

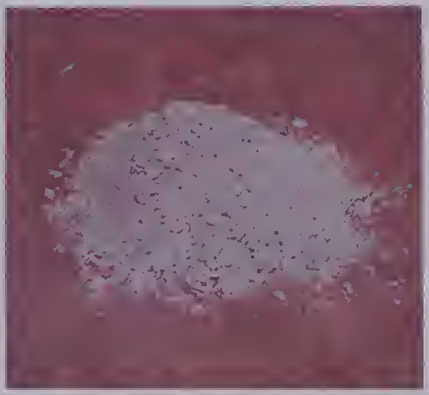
Mud almost always has particles of rock in it. Many of these are even smaller than sand grains. Next to sand grains in size are particles of *silt*. Even smaller than these are particles of *clay*. You cannot see clay particles without a microscope—and sometimes not even then.

Which do you predict will sink faster in water, a sand grain or a tiny pebble? Make a test to find out. Be sure that it is a fair test.

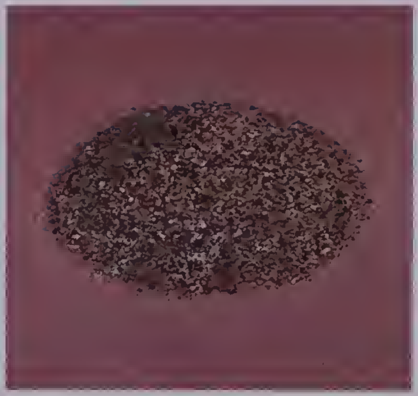
Pieces of rock. These pictures show pieces of rock of different sizes. All of them were once part of bedrock. They have come loose over the years. Pieces of rock come loose in many ways:

- Water and air act on some kinds of rock, causing new substances to form. These may fall apart or wash away.
- Water often freezes in cracks in rock. The ice takes up more space than the water did. It may push the rock apart.
- Some kinds of rock break up just by becoming wet and drying out. In some places this happens again and again.
- Bits of rock are worn off when sand and pebbles knock and scrape against bedrock. This is caused mostly by running water.

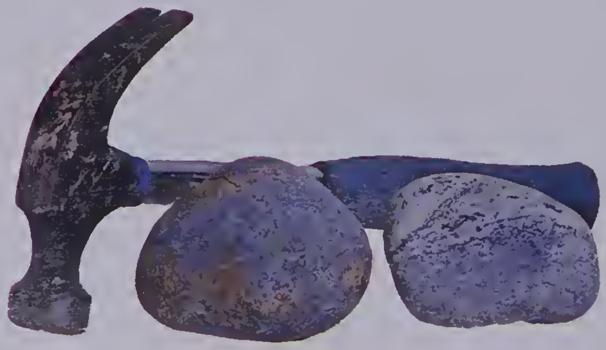
After pieces of rock come loose from bedrock, water moves them. Creeks and rivers may carry them along. Then, if they get to lakes or the ocean, they settle there.


Clay

Silt

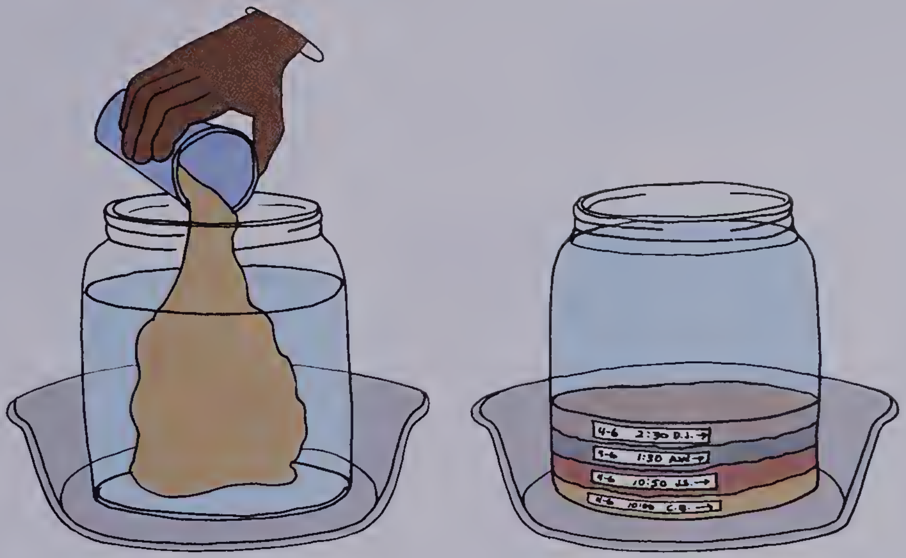

Sand

Pebbles


Cobbles with hammer

Boulder

When rock particles settle in water, they tend to form layers. Why do you suppose this happens? With your classmates, you can find out.



SOMETHING TO TRY

First find a large jar with a wide mouth. Get mud samples from many different places. Fill the jar almost to the top with water. Set it in a basin or wide pan. This will keep the table or desk from getting wet if any water should overflow.

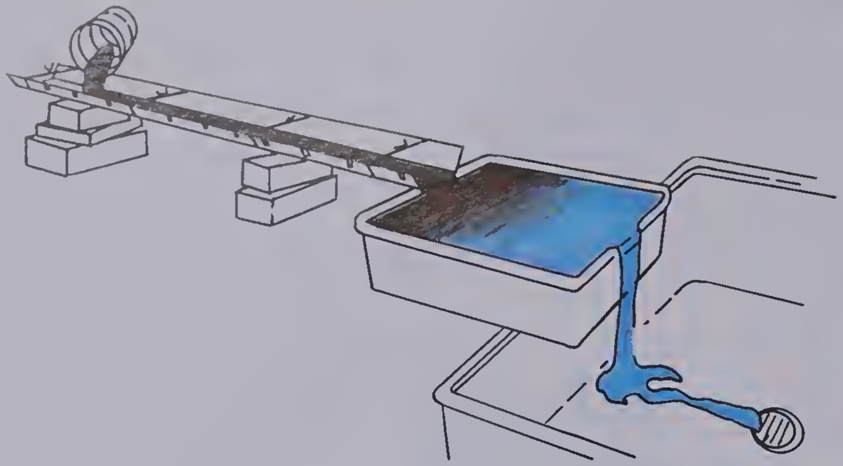
Next, mix several spoonfuls of mud and a cupful of water in a can. Then pour all the mud and water into the jar, all at once.

After the water in the jar has cleared, pour in some more mud and water. Still later, after the water has cleared once more, do this again. You may have to dip out some water to keep the jar from overflowing. Make sure, though, that you do not stir up the mud at the bottom of the jar.

Everyone can take turns adding mud and water to the jar. Try to use mud of different colors. And be sure to keep records. You might stick some tape to the jar. Then each layer may be marked with an arrow. Whoever added the layer should also write the date and time, and initial it.

Can you see why the mud forms separate layers in the jar? Watch closely when someone adds some. Which of the rock particles sink faster—the larger or the smaller ones? Which form most of the bottom part of a layer? Which settle on top? How can you tell where one layer stops and the next layer begins?

When there are many layers in the jar, can you tell which is the oldest? Newest? How do you know?



Layers deposited by streams. Some pupils set a deep pan at the edge of a sink. They placed it so that it would overflow into the sink. Then they filled the pan with water.

Next, they bent a large piece of strong cardboard to form a trough. They lined this trough with a sheet of plastic. They also tied string around it to hold up its sides.

The pupils then set the trough at a slant, on blocks. They set it so that it would drain into the pan of water. After this, one of them poured some very muddy water into the upper end. And later, after the water in the pan had cleared, someone poured in more muddy water.

Then, for several days the pupils took turns adding more muddy water a few times each day. They used mud of a different color each time. They kept careful records of what kind of mud they used.

In four days, the pupils added muddy water 12 times. After this, they dipped almost all of the water out of the pan. But they were careful not to stir up the mud on the bottom.

They let the pan stand until the mud was almost dry. Then they cut out a piece of the mud and looked at it. It showed 12 thin layers. The pupils were surprised. They could match these layers with the records they kept!

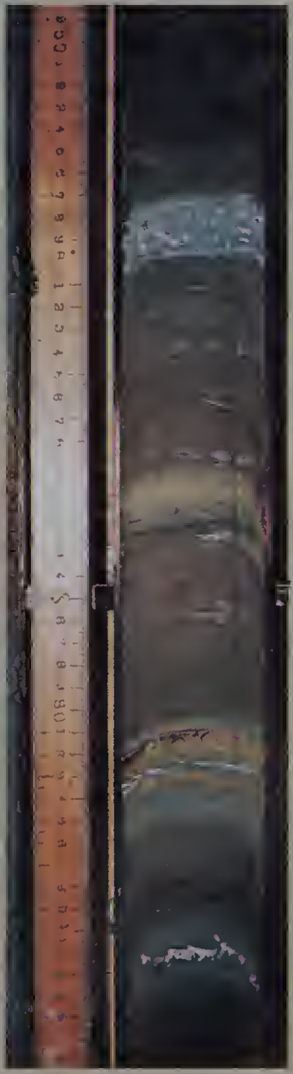
In much the same way, streams may deposit layers of mud. This happens when creeks or rivers flow into ponds, lakes, or the ocean. The running water is slowed down. This lets the mud in it settle. The mud often forms layers on the bottom of the water.

Material that settles is called *sediment.* Much sediment, such as sand, silt, and clay, is nothing but rock particles. But some sediment comes from dead plants and animals.

Sediment on the ocean bottom. Scientists on this ship are getting a sample of sediment from the bottom of the ocean. They are using a core sampler. This is a heavy metal tube on a long cable. When it drops to the ocean bottom, it sticks into the sediment. Since the tube is hollow, some of the sediment becomes caught inside.

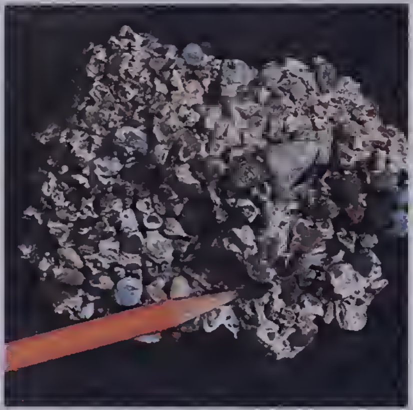
Then the scientists raise the core sampler by the cable. When they get it on the ship they remove the core sample inside it. Later they study the sediment.

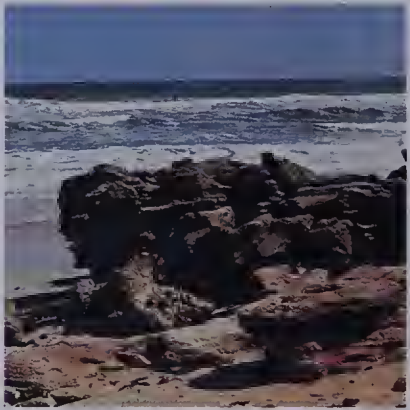
Look at the layers of sediment in this core sample from the ocean bottom. How do you suppose they may have been formed?

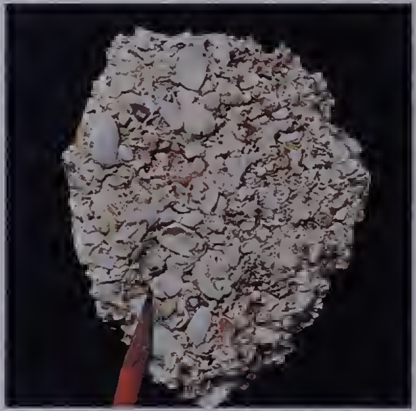


These pebbles in a gravel pit are stuck together. Each pebble has a coating of *mineral* material on it. This was left by water that soaked through the gravel. The mineral material holds the pebbles together. It acts as a cement.

This rock on the seashore is made mostly of shells and pieces of shells. These have become stuck together somewhat like the grains in damp sugar. But it takes shells much longer than grains of sugar to become stuck together.







SOMETHING TO TRY

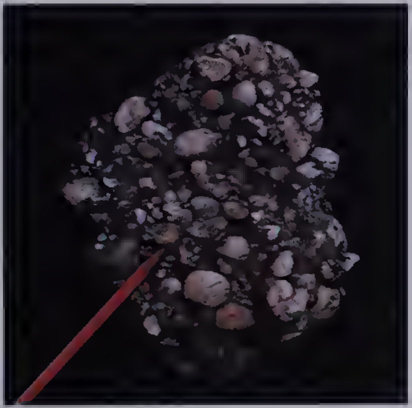
Vinegar acts on some mineral material and makes it dissolve. The cement that holds together these pebbles is this kind of mineral material. Vinegar acts on the cement, causing the pebbles to come apart. However, vinegar does not do this to all kinds of mineral material.

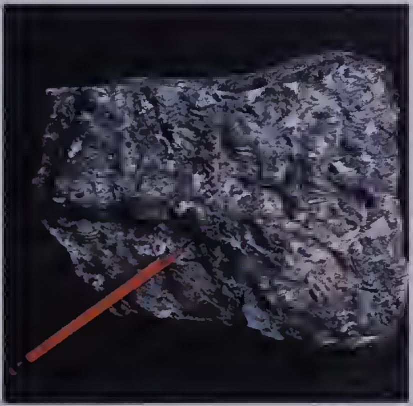
Sedimentary rocks. Pebbles cemented together form a rock that could be called pebblestone. But this rock usually is known as *conglomerate.*

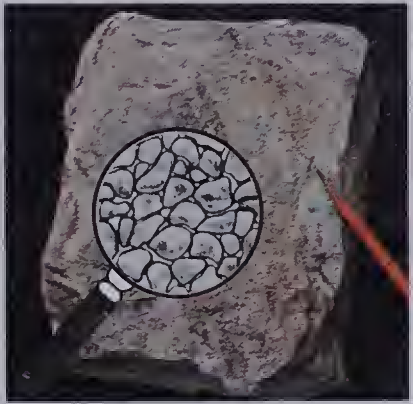
A rock made of shells cemented together is sometimes called shellrock. It is really a kind of *limestone.*

In many places grains of sand have been cemented together by mineral material. The rock they form is known as *sandstone.*

Mud, too, often has hardened into rock. This is called *mudstone.* If it breaks into thin, flat pieces, it is called *shale.*


Conglomerate

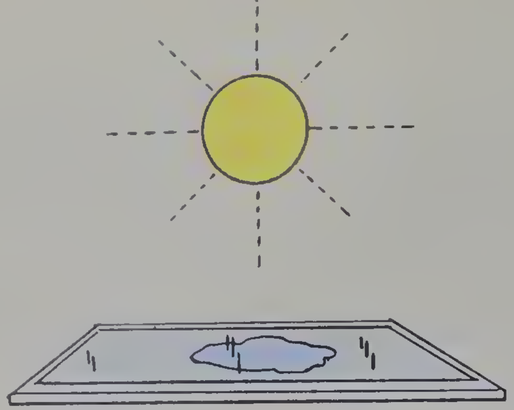

Limestone

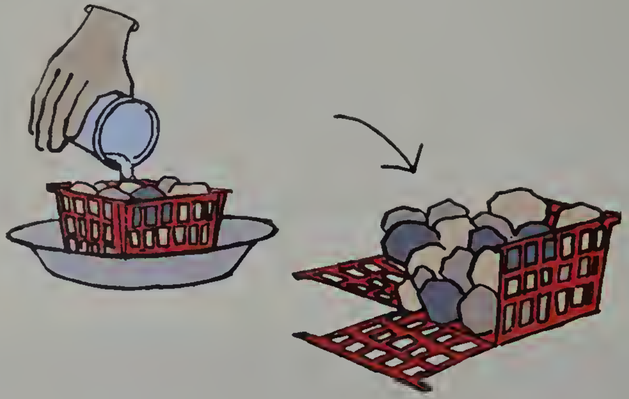

Sandstone

Mudstone

Pebbles, sand, mud, and shells all settle in water. This is why they are called sediments. Sometimes sediments settle on land, too. For example, ash blown out of a volcano settles on land and in water.

Many sediments, over a long period of time, become hardened into rocks. These rocks are known as *sedimentary rocks.*





SOME THINGS TO DO

1. Find out whether water from different places has dissolved mineral material in it.

First, get a clean piece of window glass. To keep from being cut, put tape around its edge. Now lay the glass flat. Then put a few drops of clean water on it, in a small pool.

Let the water evaporate. Then hold the glass up to the light and examine the place where the water was. Can you see a coating on it? If so, this is material that was dissolved in the water.

Try this with different samples of water. Use water from rain, wells, creeks, and other sources. How much mineral material do you find in each sample?

2. Make a model of conglomerate or a giant model of sandstone.

Set a berry basket in a pan. Fill it with pebbles. Then mix a few spoonfuls of glue with a little water. Spoon this mixture over the pebbles. Keep doing this until they are all wet. Now let the glue dry. Later, cut away the basket.

The glue acts much like the mineral cement in conglomerate. But the mineral cement is not the same as glue. Nor did it get there in the same way!

Would there be room for water inside your model? Would you predict that water can soak into real conglomerate or sandstone? Test your prediction.

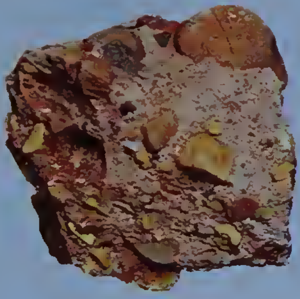
SOME SEDIMENTARY ROCKS (pictured on page 53)

1, 2. Conglomerate—pebbles, cemented together, often with sand between them.

3, 4. Sandstone—sand that has been cemented into rock.

5. Siltstone—hardened silt, a sediment finer than sand and coarser than clay.

6. Mudstone—mud that has hardened into a kind of rock.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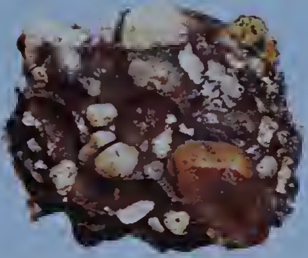
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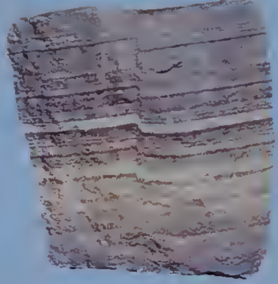
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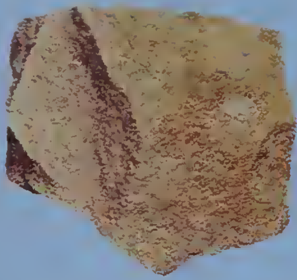
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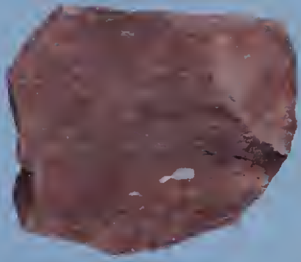
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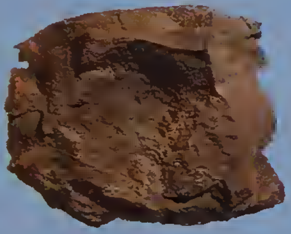
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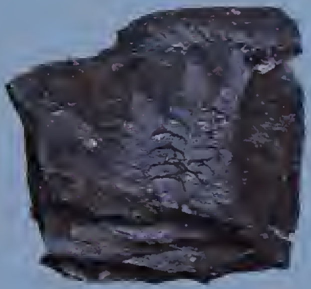
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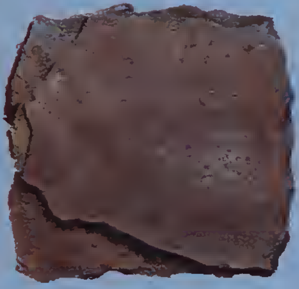
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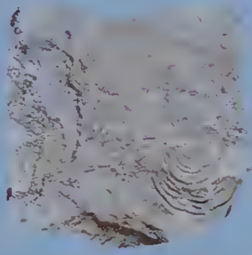
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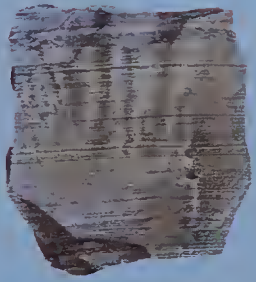
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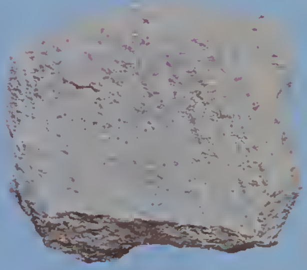
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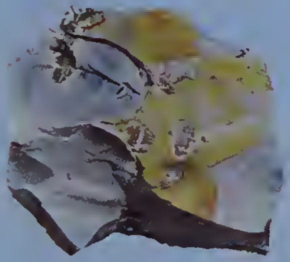
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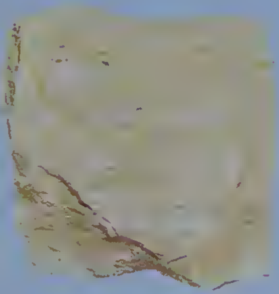
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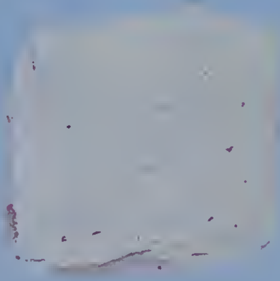
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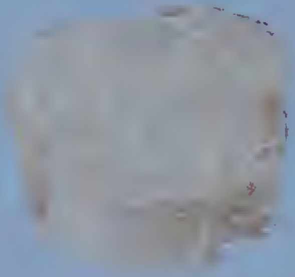
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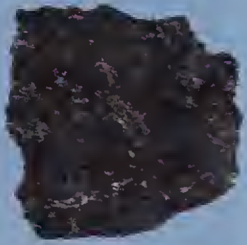

16

7, 8. Shale—clay or mud hardened into rock that breaks into thin pieces.

9, 10, 11. Limestone—shells cemented together or other hardened limy sediments.

12. Chert or flint—a hard material often found within limestone.

13. Dolomite—a rock like limestone, with much magnesium.

14. Volcanic ash—fine rock particles blown out of volcanoes.

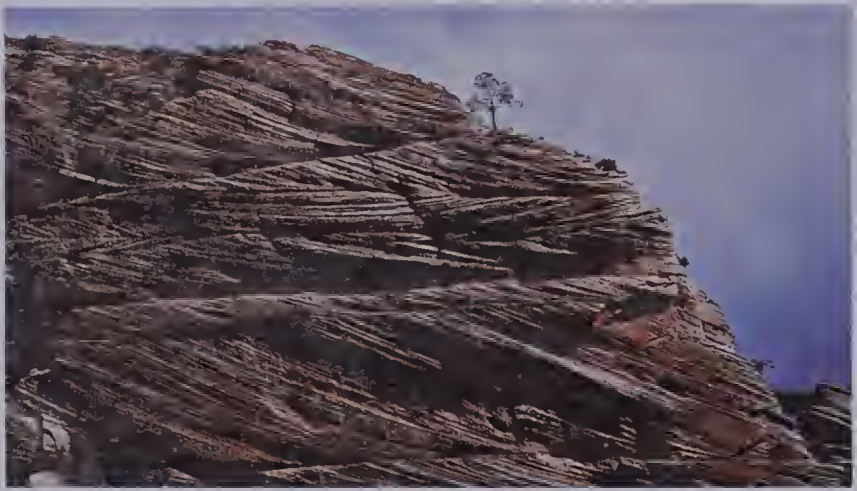
15. Rock salt—salt left behind when water evaporated.

16. Coal—a rock that was formed from remains of plants which lived long ago.

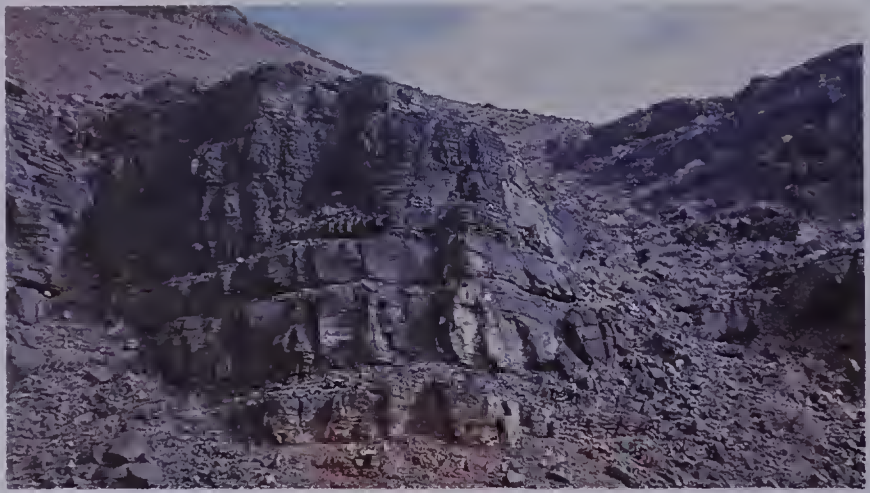
These pictures show layers of several kinds of sedimentary bedrock.

Can you see any bedrock near where you live? If not, might you be living on top of bedrock, even though it is hidden? Might it be sedimentary bedrock?

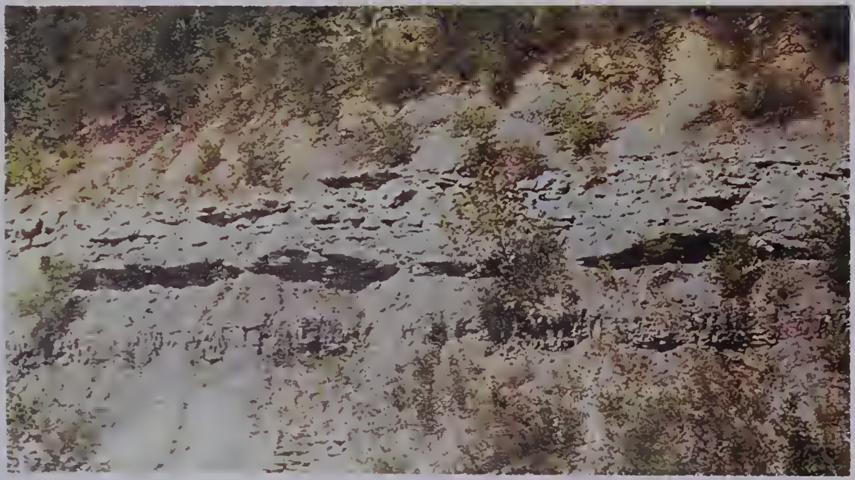
Sandstone in Utah



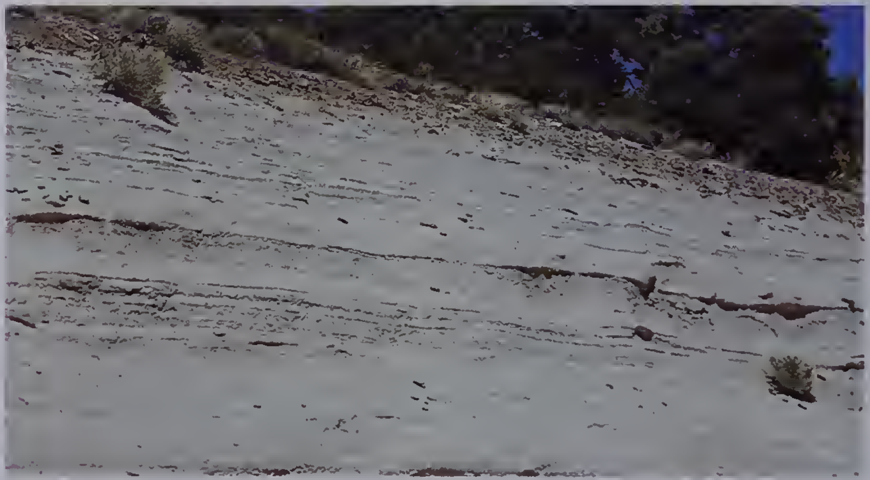
Limestone in California



Coal, shale, and sandstone in Ohio



Volcanic ash in Nevada



Clues to the Past LESSON 3

Sedimentary rocks often give us clues to what the earth was like in the past. For example, the shale in this cliff shows that there was once a lake there. This lake must have been very large, covering the area where Wyoming, Utah, and Colorado are today.

The thin, even layers of shale show that the water in the lake was still. The many changes in color of the layers suggest that there were seasons then, as now.

Many skeletons have been found in these layers. This suggests that fish and other animals lived in the water.

Look again at the pictures of rock layers on the opposite page. What clues to the past do they give you?

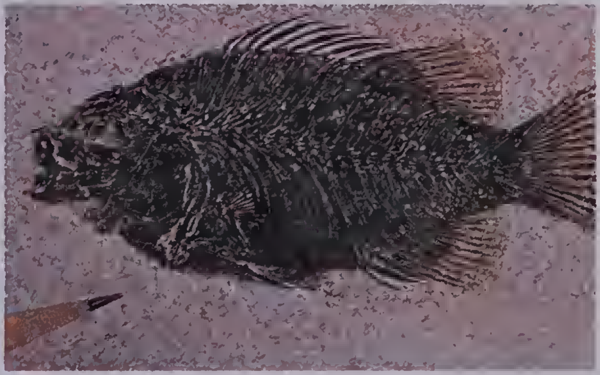
To help you answer this, here are some things that you should know:

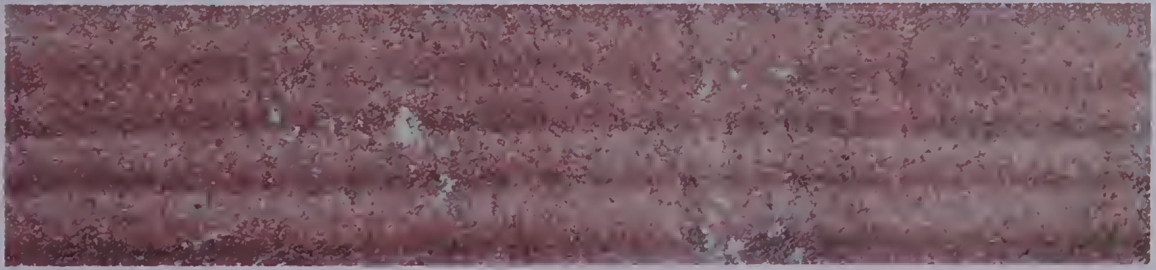
Today, in some places, wind blows dry sand into dunes. The sand inside these dunes is in layers. Why do you suppose that these layers often slant?

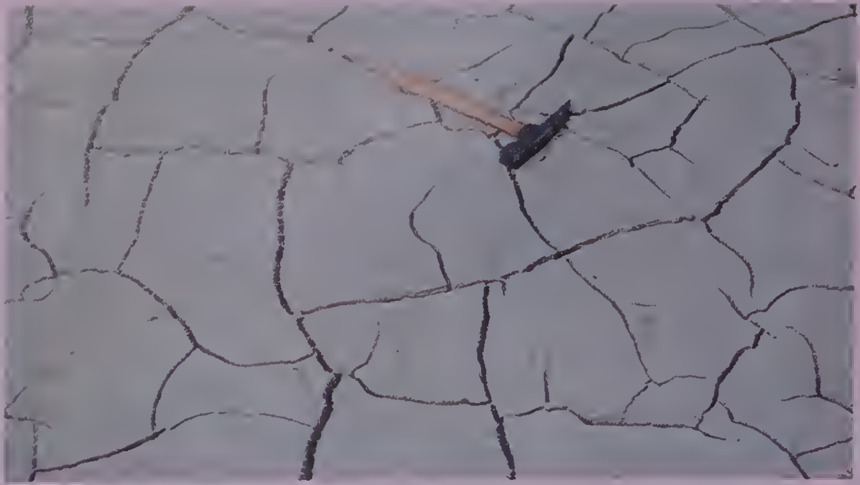
Limestone often contains the shells and skeletons of sea animals. How do you suppose that they got there? But how can it be that the limestone is sometimes far from the sea?

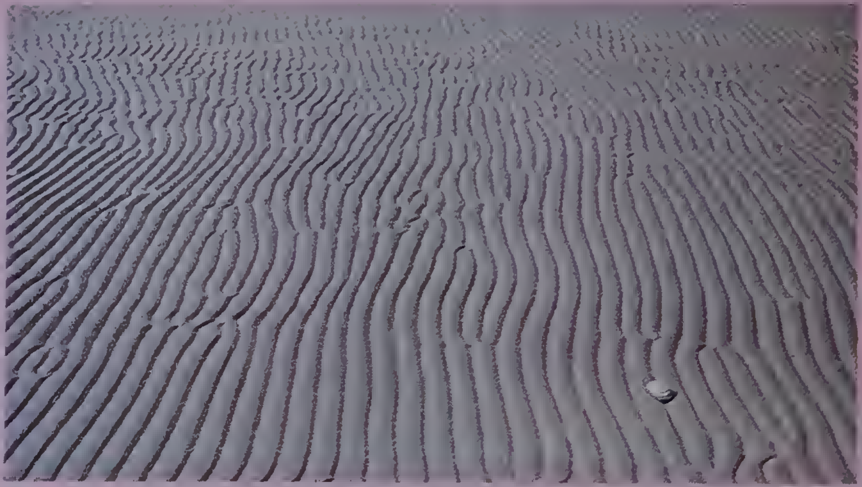
Coal in the ground is usually between layers of shale and sandstone. All these rocks may contain parts of trees. What does this suggest?

Every now and then, some volcanoes blow out fine rock dust called ash. This *volcanic ash* is a sediment. Where do you suppose it settles, and where do you think it forms the thickest layers?









Clues left in rocks. During a flood, a river overflowed its banks. It left mud. After the flood, the mud dried out. It shrank as it dried. Cracks opened up in it, as shown above.

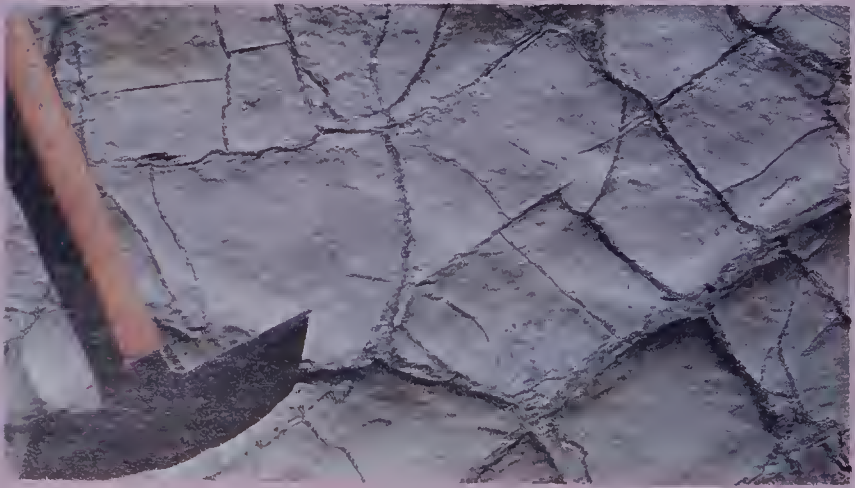
Often there are mud cracks like these in dried-up puddles. Have you ever seen any?

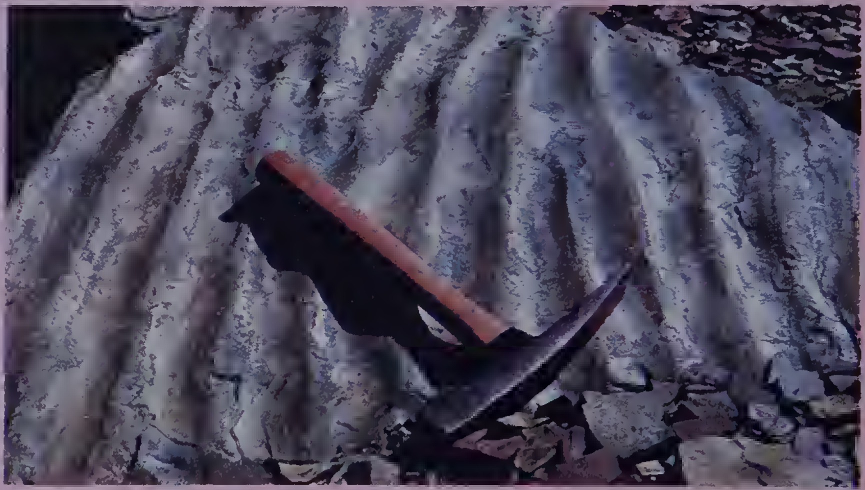
The picture below shows shale with markings that look like mud cracks. But they aren't open.

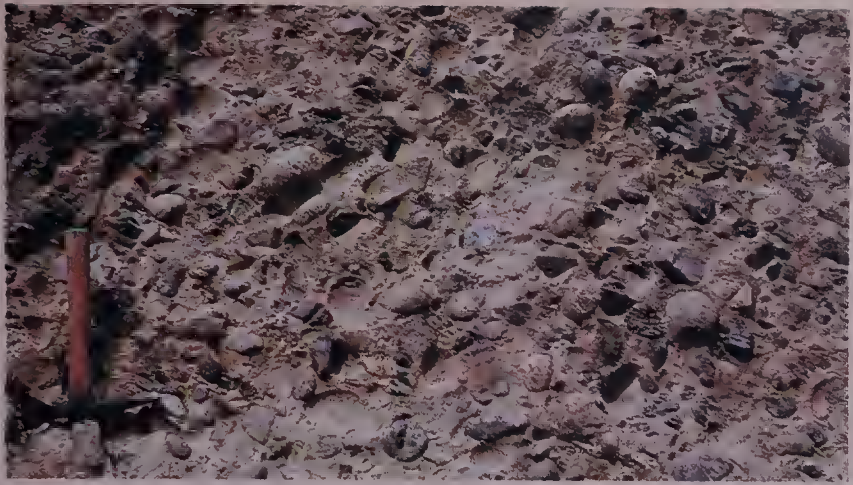
Geologists think that very long ago mud dried out and cracked. Then the cracks became filled with sand. Later, both the mud and sand hardened into rock.

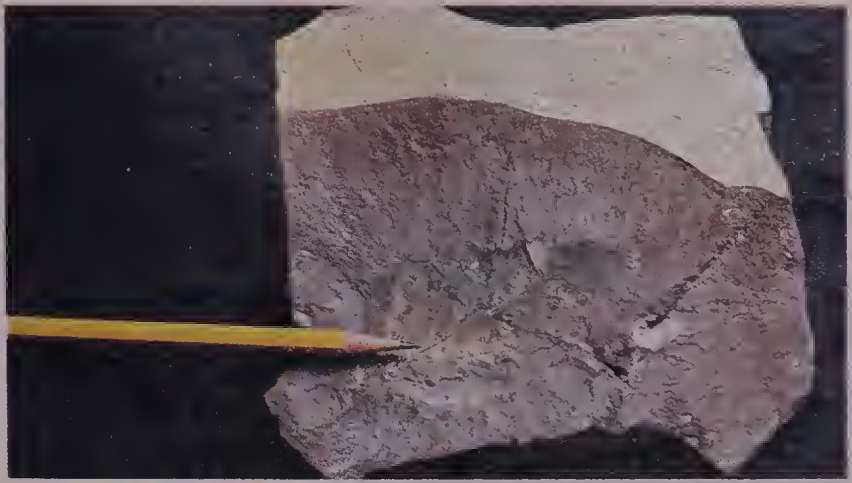
Water flowing over a sandy beach made the *ripple marks* in the sand shown above.

Geologists think that the wavy markings in the sandstone below are ancient ripple marks.



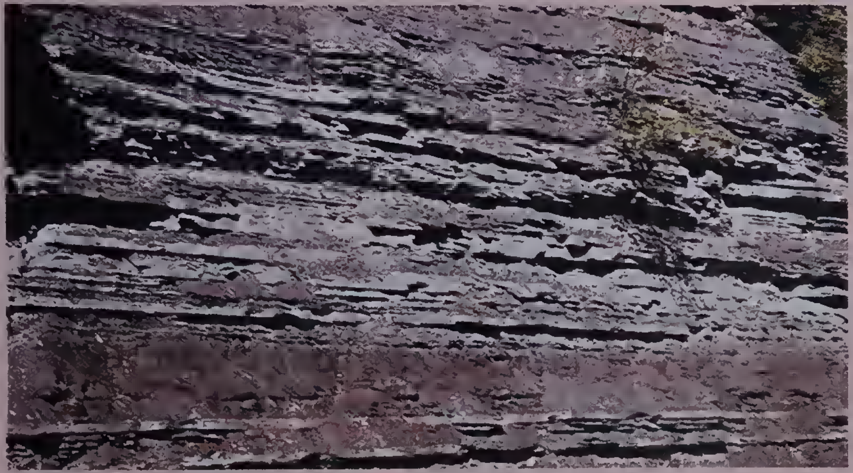






The pebbles in the conglomerate above are smooth and rounded. How could they have gotten like this? They must have been knocked and scraped against one another by moving water. Today, where is this happening to loose pebbles?

The picture below shows a cut made in a hill when a road was constructed. The *road cut* shows layers of sandstone and shale. These seem to have formed from sand and clay deposited in water. What might have caused the changes—from sand to clay, and back?



The piece of siltstone above was likely soft sediment on the bottom of a body of water. It has in it the marks of leaves. How do you suppose that these came to be in the rock? How could you tell what kinds of trees were living by the body of water at the time?

A key to the past. These are a few examples of how geologists can infer what took place long ago. They do this by carefully observing clues in rocks. But before they can infer what took place in the past, they must first observe what is taking place today.

For this reason, geologists often say, "The present is a key to the past."

Raised layers. This hill in New York State is more than 200 m above sea level. The bedrock in it is made up of mixed layers of sandstone and shale.

In the layers near the top people have found the impressions of clam shells. They also have found the impressions of starfish, or sea stars. Perhaps the sea stars were feeding on the clams when they both were buried.

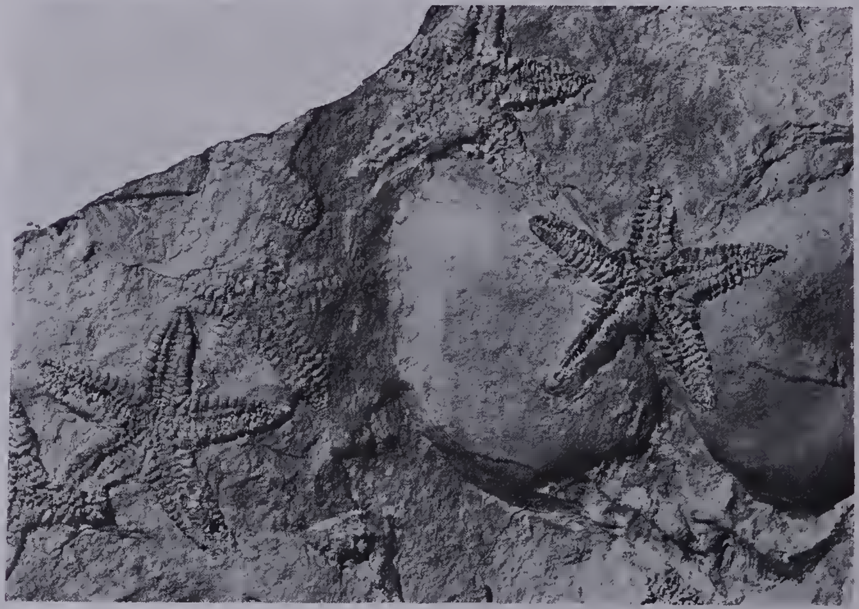
Sea stars, today, feed on clams. And sea stars, today, live only in the sea. So geologists infer that the layers in this hill were once sediment on the sea bottom. How, then, can it be that these layers are now high above sea level?

Perhaps you can suggest a possible explanation, or *hypothesis*. An hypothesis is one explanation, but it may not be the right one. It may or may not prove to be correct!

In many other places, too, there are ancient sea deposits that are now high above the sea. Some are very high, more than 3000 m above sea level.

Could the sea have gone down this much? If so, it would have had to do so all over the earth! Then what happened to all the water?

There seems to be a better hypothesis. Perhaps the sea bottom came up. Layers of sea sediments were pushed up, and became dry land. In some places they even formed hills and mountains!

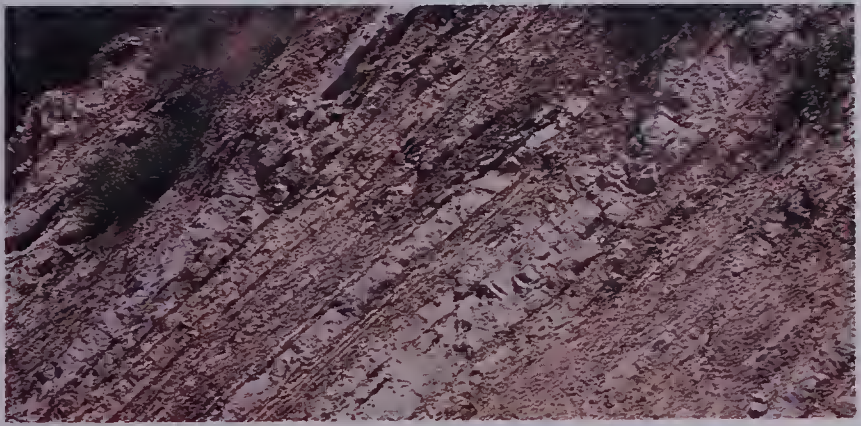


Slanted layers. This road cut shows slanted layers of shale and sandstone. These rocks were once mud and sand on the bottom of a sea. In them are many shells of ancient sea animals.

Can you suggest why these layers slant so steeply? Could they have been deposited at such a steep slant in water? Or might they have become slanted later?

In many other places bedrock layers formed of sediments deposited in water slant very steeply. In some places, they even stand upright. However, layers of sediment usually cannot be deposited at such a steep slant in water. And, so, geologists infer that the rock layers became slanted only after they were deposited.

The slanting must have been done by great forces deep within the earth. And, as a rule, it seems to have gone on very slowly.



SOMETHING TO TRY

How steeply can you get layers of sand and mud to form?

Put a few handfuls of clean sand in a jar. Fill the jar with water. Screw on the lid. Slowly tilt the jar to one side.

How steeply can you make the sand slant before it slides? Can you get it to stay as steep as the rock layers in the picture?

Now make the sand slant as steeply as you can. Set the jar down gently. Carefully remove the lid without making the sand slide.

Next, sprinkle a little powdered dry mud or clay on the water. Wait until it settles. Is the layer that it makes as steep as the sand?

After this, sprinkle some dry sand on the water. How steep a layer does it form?

Now do you think that the layers in the picture could have been deposited at such a slant? If not, how do you suppose they became so slanted?

Dave's discoveries. When Dave was about 10 years old, he liked to explore the vacant lots near his home. Here he discovered pieces of rock with shells and other interesting things in them. The best ones came from gullies and from old stone walls.

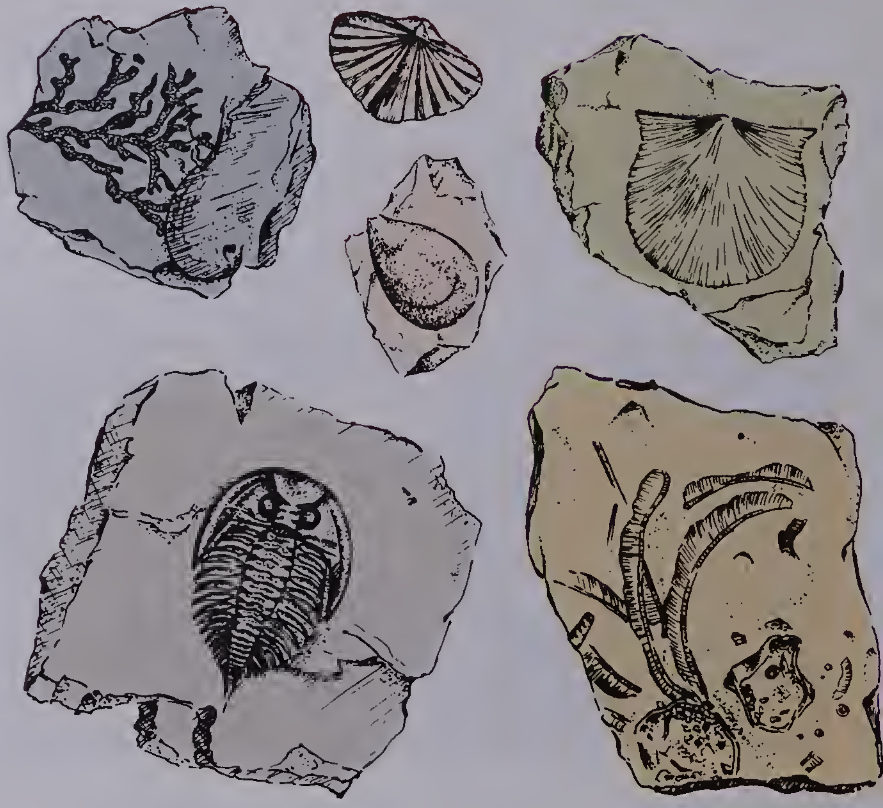
Sometimes in deep holes dug for new houses, Dave could see layers of bedrock in the ground. These were firm and solid far down. But higher up they were soft and crumbling. On top, the crumbling bedrock was covered by soil.

The firm rock had shells in it. But it was hard to get them. It was easier to pick them up where they had come loose from crumbling rock.

To protect the things he found, Dave wrapped them in newspaper. When he got home, he washed them carefully and put labels on them. Then he took some of the best ones to show at school.

It seemed to Dave that the layers of bedrock must once have been sediment under water. He supposed that the shells came from animals that lived in the water. When these animals died, their shells became buried by the sediment. Then this later hardened into rock.

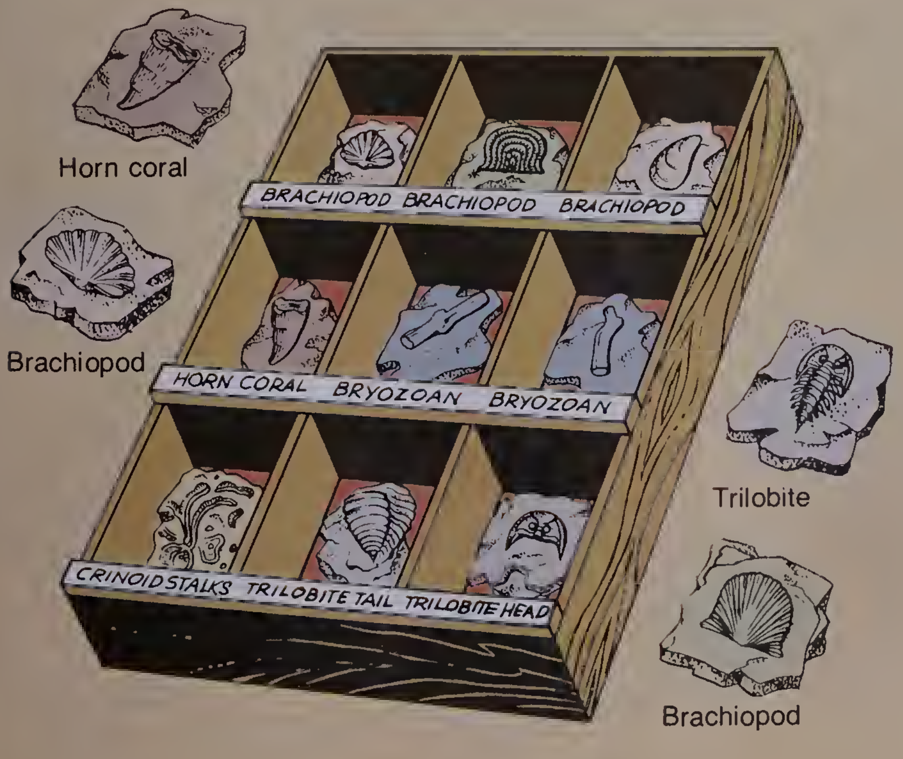
To find out more, Dave got books from the library. He read that shells and other remains of animals and plants in rock are called *fossils*.



In time, Dave learned that most of his fossils were the shells of *brachiopods*. These animals live only in the sea. They are still living in the sea today. But they are not as common as they were long ago.

Dave also learned that some of his fossils were the skeletons of *corals*. Corals, too, are animals that live only in the sea.

One thing puzzled Dave. Why was he able to find fossils of sea animals near his home? He lived hundreds of kilometres from the sea, and many metres above sea level! Could it be that the sea covered his home area at one time? If so, why was it no longer there?



Dave found fossils of other kinds of sea animals too. These had strange names, like *trilobites, crinoids,* and *bryozoans*. Trilobites became very interesting to him because he read that these animals are no longer living. He was able to collect many fossils of trilobites. Mostly these were just pieces of skeletons. But he studied all the parts he could find—even their eyes!

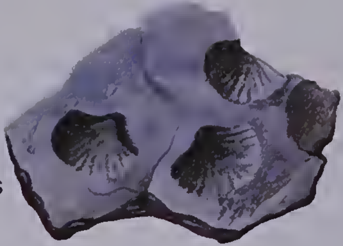
Later, Dave became greatly interested in fossil crinoids, or "sea lilies." He learned that these were not plants, but animals related to sea stars. Many of them may have looked like flowers attached to the sea bottom by long stalks. Unlike trilobites, crinoids are still living today in the sea.

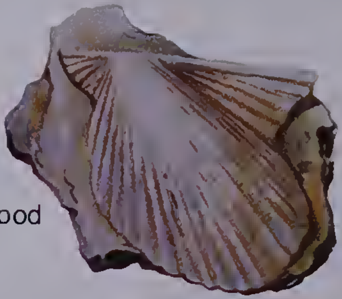
While in high school, Dave received top honors at the State Science Fair for his study of crinoids. He even discovered a kind of fossil crinoid that nobody had ever found before!

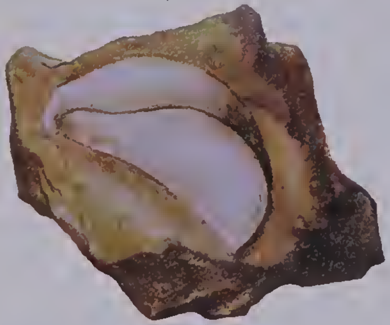
In time, Dave went to college to study geology. Best of all, he liked to go on fossil-collecting trips to faraway places. He kept finding out more about crinoids. He was even able to dive to the bottom of the sea to study living crinoids.

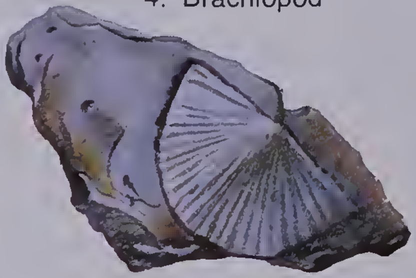
Today Dave is a college professor. He still studies fossils and teaches others about them. Now his students make their own discoveries!

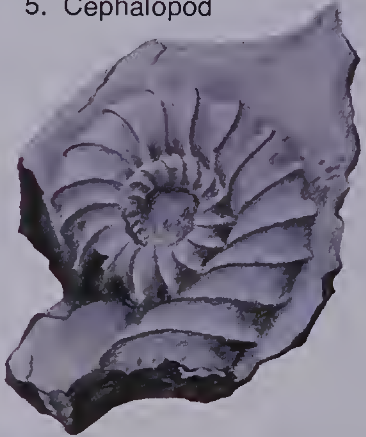
Fossils are often found in sedimentary rocks. These came from Illinois, but others like them are found in Ontario, Michigan, and New York.

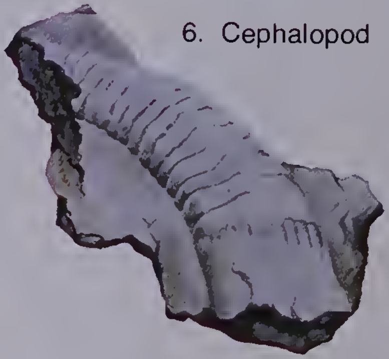

1. Brachiopods


2. Pelecypod


3. Brachiopod


4. Brachiopod


5. Cephalopod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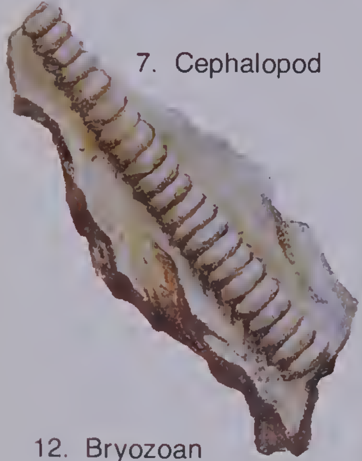
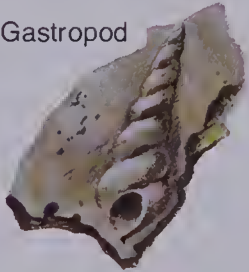
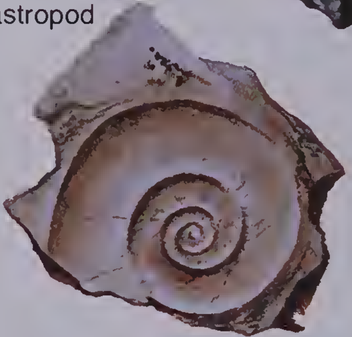
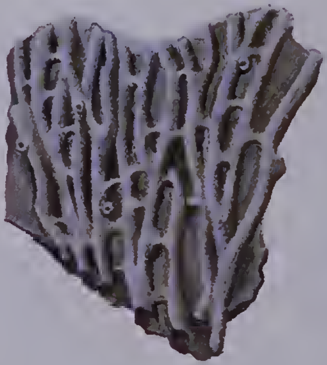
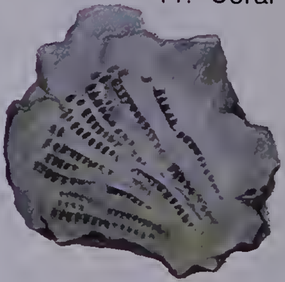
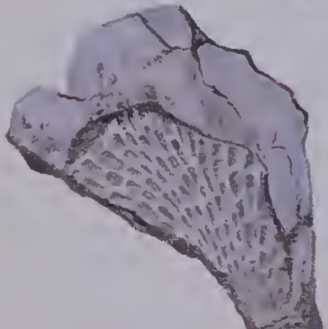

7. Cephalopod

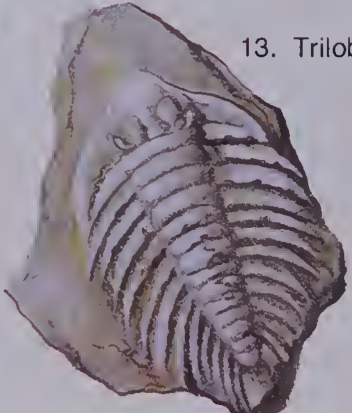

8. Gastropod

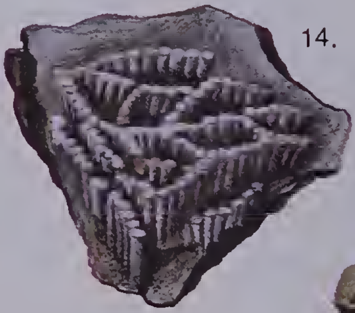

9. Gastropod

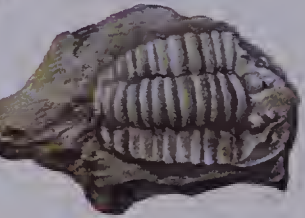

10. Coral

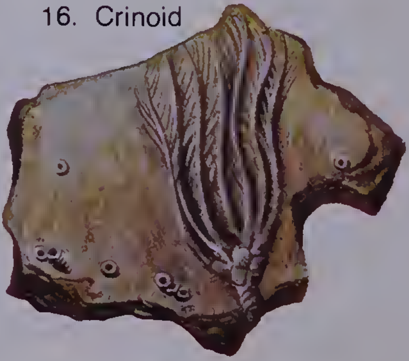

11. Coral


12. Bryozoan

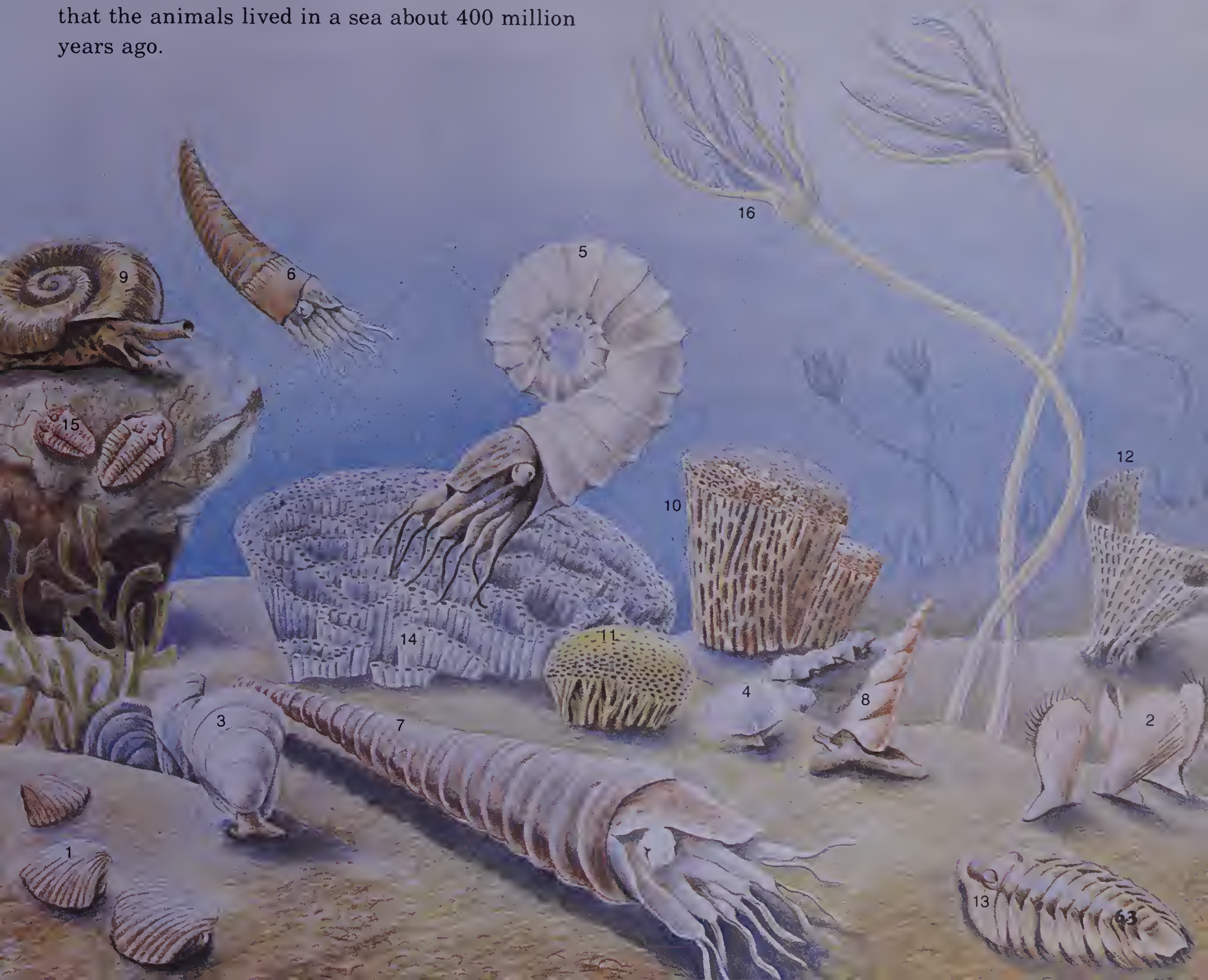

13. Trilobite


14. Coral


15. Trilobite


16. Crinoid

Scientists who have studied these fossils think that the animals lived in a sea about 400 million years ago.



SOMETHING TO DO

You and your classmates can have fun by making some "fossils." Later, you can discover them.

First find an old dishpan or other deep pan. Then put in mud, a little at a time. Keep adding water, and stir, to make the mud soupy.

From time to time, drop a shell into the mud. Or perhaps add some fish bones or a crab claw. You might even put in a chicken bone or feather, or a leaf. Everyone should add something.

When the mud is at least 10 cm deep, let it stand. Dip out the extra water. Then let the mud dry out. This may take several days. To speed it up, set the pan in a warm, dry place.

After the mud has become dry and hard, break it apart. Look for the "fossils" in it. These are not only the shells and other things, but also their impressions in the hardened mud.

The mud is much like sediment on the bottom of an ancient sea or lake. The shells and other things are like animals and plant remains that sank to the bottom. Then what is the hardened mud like?

Where might shells and other remains of animals and plants become buried in soft sediment? Then how might the sediment become hard? What would it form? What would the shells and the other things buried in the sediment form?

How fossils were formed. Most fossils were formed by being buried in sediments. Usually this happened under water. Even so, the soft parts of the plants and animals nearly always decayed. Mostly only their shells, bones, teeth, and other hard parts were left.

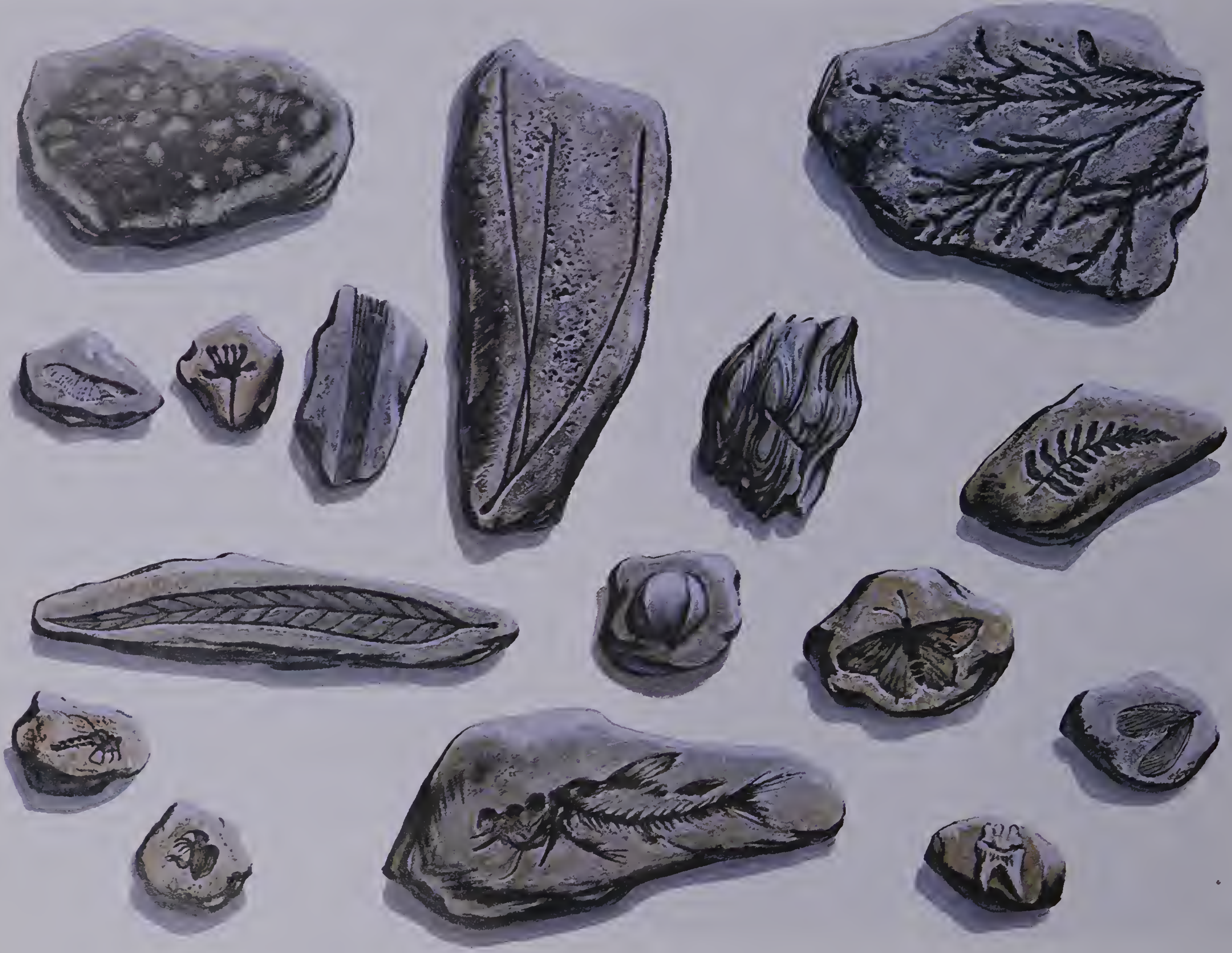
Sometimes, however, the remains of plants and animals have been preserved in other ways. In some places, this is still going on today.

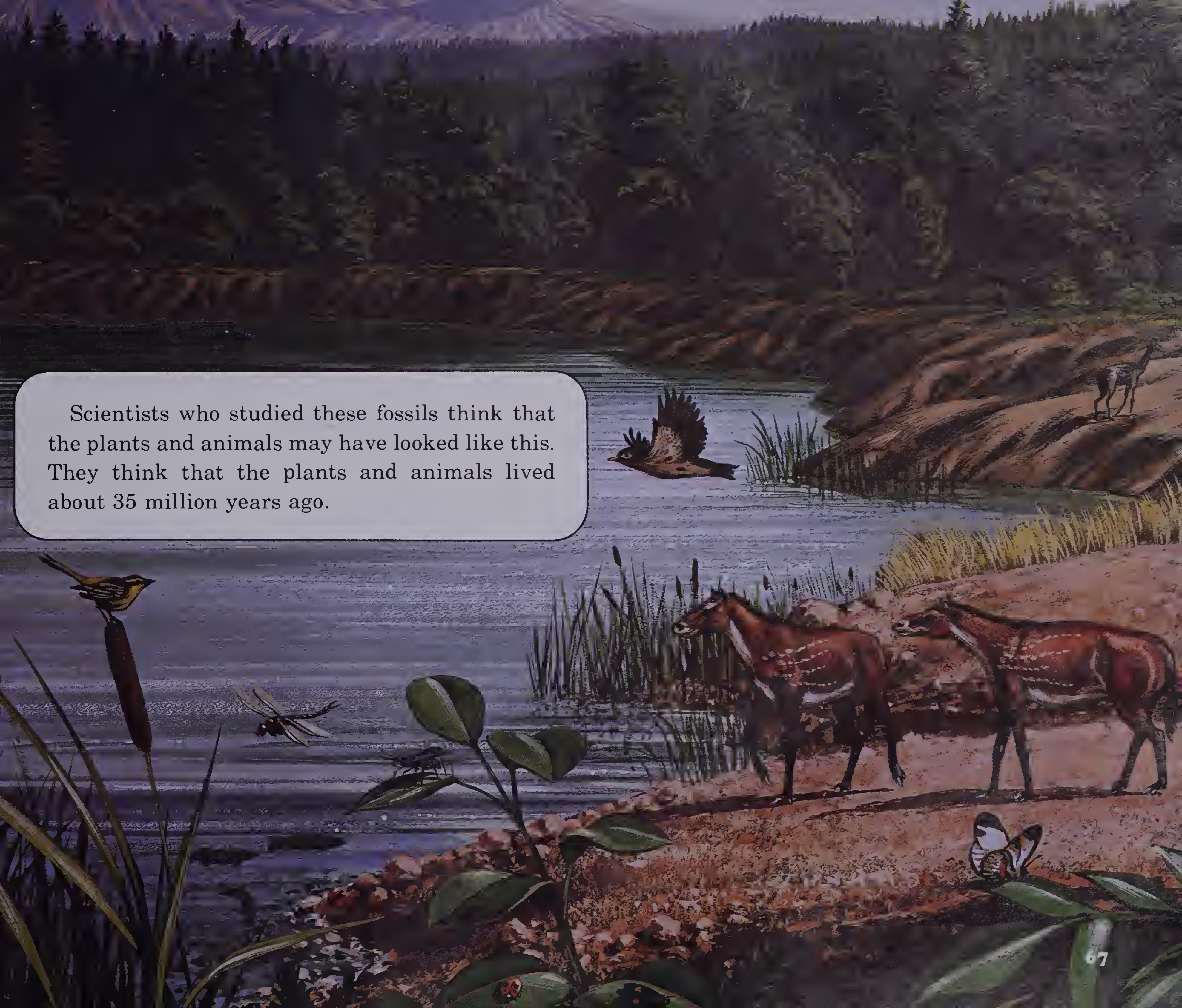
For instance, in a few places in California tar seeps out of the ground. It forms pools and slow-flowing streams. Animals keep getting stuck in it. Mostly this happens at night, or when they drink from puddles that cover the tar.

This seems to have been going on for many years. In the ground, there is a great deal of tar that has hardened. It contains thousands of bones and teeth.

From these remains, scientists have put together whole skeletons. These show what kinds of animals lived there long ago. Many of these were small animals, like rabbits and lizards. But some were much larger. There were kinds of elephants, camels, giant cats, and vultures that are not living today!

Fossils like these have been found in Colorado, Oregon, Washington, and British Columbia.





Scientists who studied these fossils think that the plants and animals may have looked like this. They think that the plants and animals lived about 35 million years ago.

Fossils are important in many ways. These are some ways:

- Fossils are the only way we have of finding out about the animals and plants of long ago.

For example, without fossils, we would have no idea that animals like this "sea scorpion" had ever lived. We would know nothing about ancient dragonflies with wings nearly a metre across.

- Fossils give us evidence of how living things have changed during the earth's long history.

Fossil bones, for example, give evidence that horses were once no bigger than dogs. And that these ancient horses did not walk on only their middle toes, as modern horses do.

- Fossils tell us a great deal about the geography of the earth in the past.

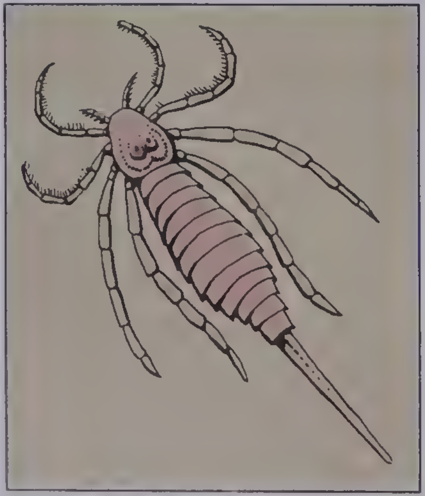
For example, fossil corals found in Kentucky show that a sea used to cover that area. And fossil freshwater fish in Wyoming give evidence that there was once a large lake there.

- Fossils often help us to match rock layers of the same age from one area to another.

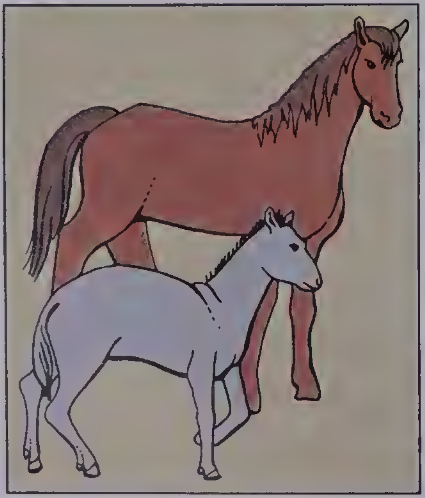
Some bedrock layers in both eastern and western North America, for example, contain similar trilobites. This suggests that these layers are about the same age.

- Fossils are some of our most important sources of energy and useful materials.

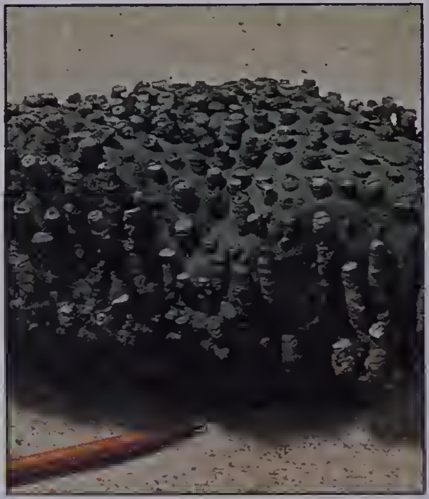
For example, coal was formed from the remains of plants of long ago. And *petroleum,* which means "rock oil" in Greek, also came from dead things of the past.



Sea scorpion



Early and modern horse

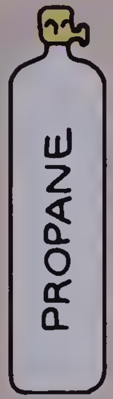


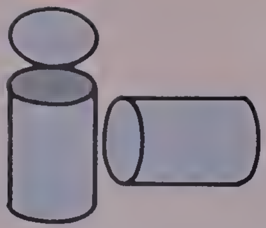
Coral

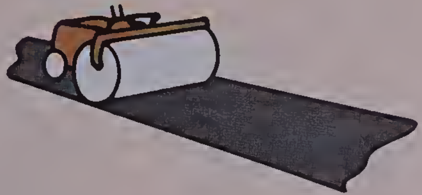
Trilobite

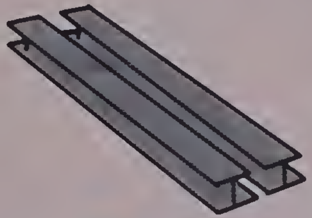
Uses of Sedimentary Rocks LESSON 5

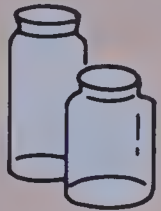
Which of the things shown in the pictures came from sedimentary rocks?

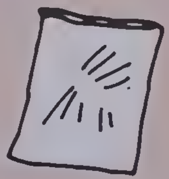


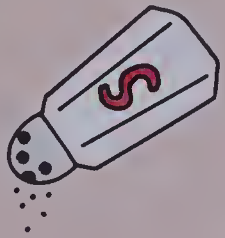


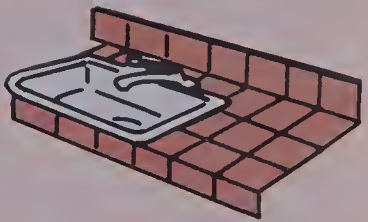


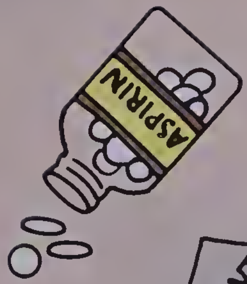


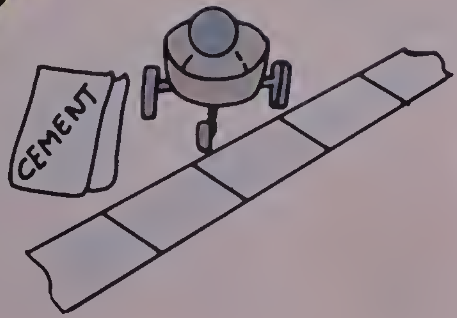


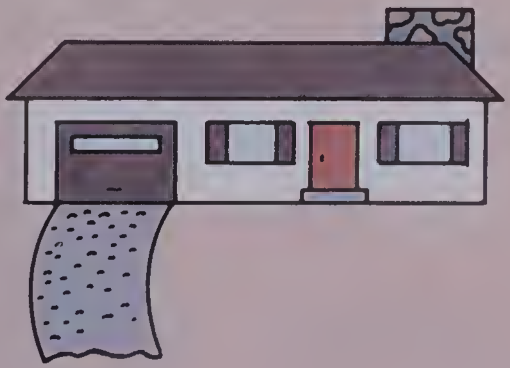




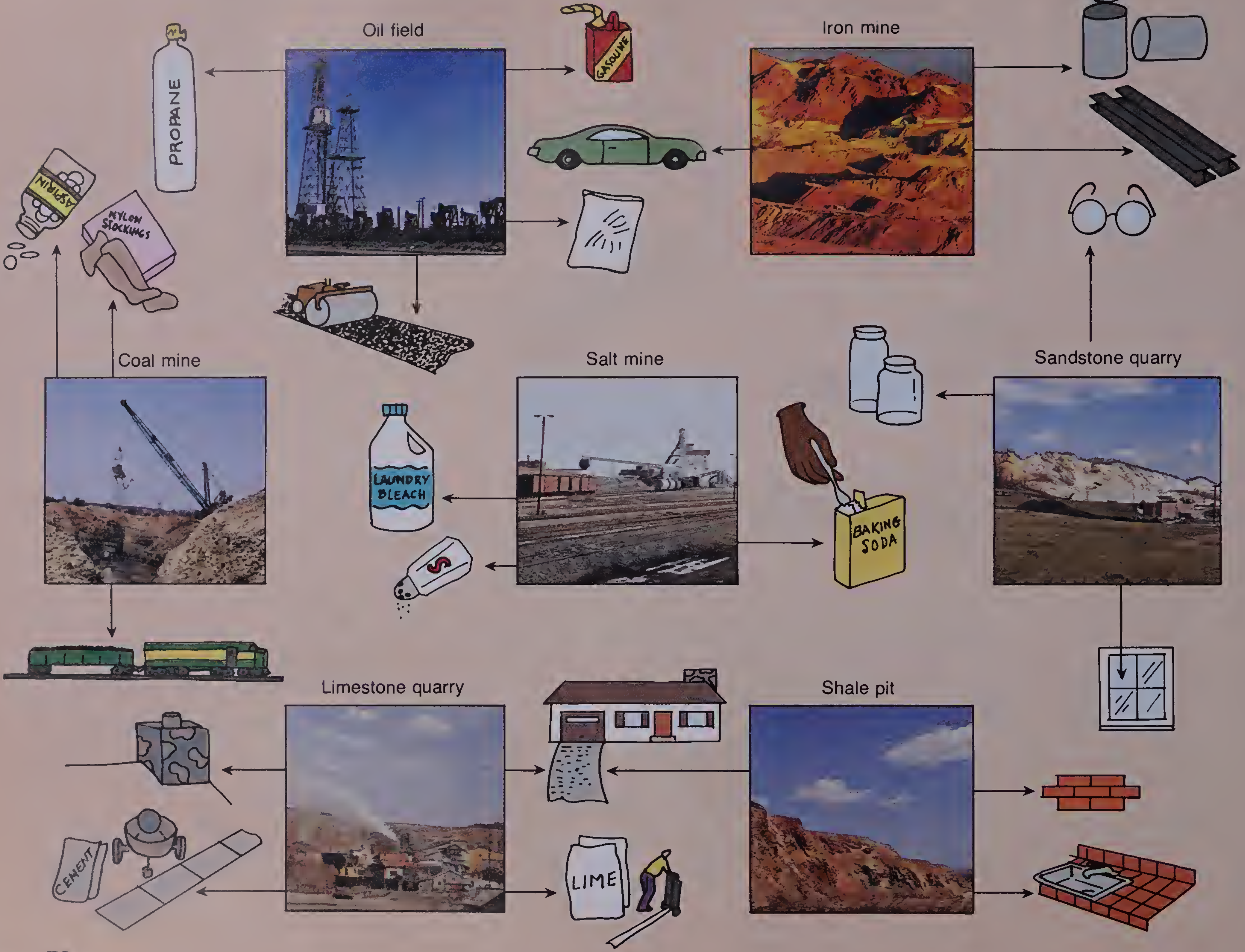








All of the things on page 69 may have come from sedimentary rocks—at least in part!



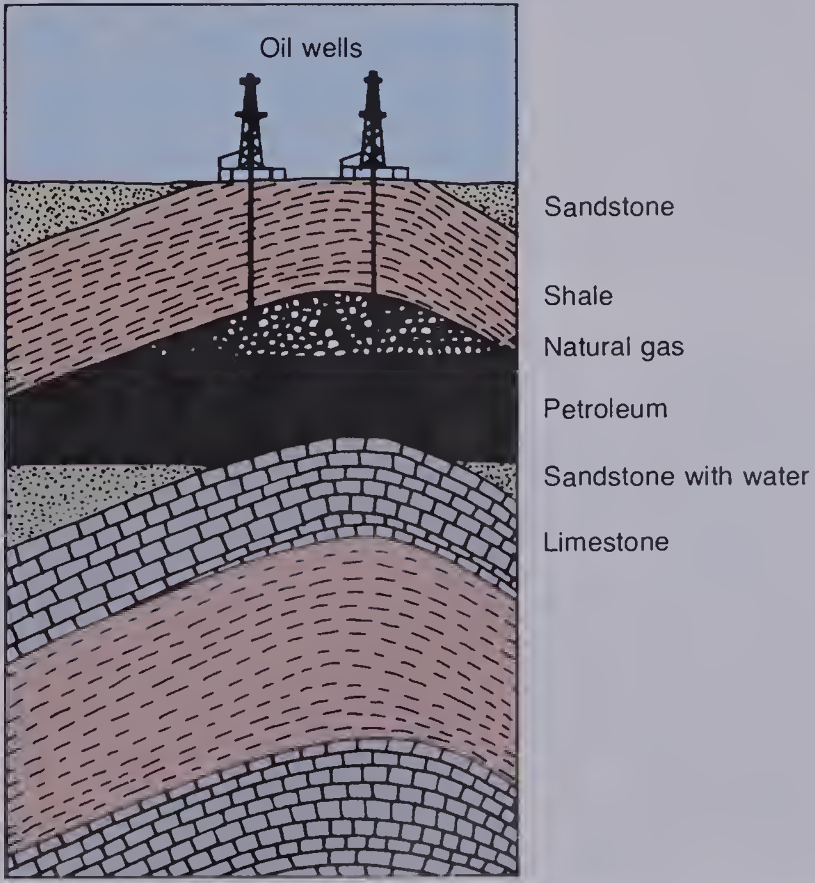
Materials from sedimentary rocks. We get a great many useful materials from sedimentary rocks. For example, we often use shale to make bricks, and limestone and shale to make cement. We use gypsum to make plasterboard for houses. And we use a great deal of sandstone to make glass.

From some kinds of sedimentary rocks we can get iron, and from others, aluminum. From still other kinds we can get large amounts of fertilizers for lawns and farm crops. Besides these things, we can make many others from sedimentary rocks. Among these are baking soda, laundry bleach, some kinds of cloth, and even some kinds of medicine.

One of the most important substances that comes from sedimentary rocks is a liquid—water. Underground, the *pores* and other spaces in bedrock are usually filled with water. When wells are drilled into this water-soaked bedrock, water runs into them. Then it can be pumped out. Water from wells is usually cold and clear.

In some places, the pores in sedimentary bedrock hold not water but *natural gas.* In other places they contain oil, or petroleum. Geologists think that both these substances were formed mostly from plants and animals of the past. For this reason, they are called *fossil fuels.* Coal, too, is a fossil fuel, since it was formed from plants that grew long ago.

For bedrock to hold natural gas and petroleum, there must be some sort of a trap. Otherwise these substances would have leaked out. In some places there are traps where rock layers have been bent upwards. But this is not enough. Above the layers containing the petroleum and natural gas there must be other layers. And these must be of shale or other rock through which these substances cannot pass. Then, to get the oil and gas, wells must be drilled through these covering layers.



SOMETHING TO THINK ABOUT

What can sedimentary rocks give us that we need never use up? What is it that we, and those who come after us, can keep forever? The pictures below give a hint.

Mt. Robson, British Columbia

Bryce Canyon, Utah

Looking to the future. We need large amounts of sedimentary rocks and materials found in them. However, in taking them out of the ground, we may spoil our environment. We must remember that other things are important, too.

For example, when we dig out coal or sandstone, we often leave scars on the land. We should smooth these over and plant trees on them. Otherwise they will look ugly.

When we dump waste rocks from mines, it may kill trees and drive away wildlife. When we wash large amounts of crushed stone, mud may be carried into creeks and rivers. There it may *pollute* the water and kill the fish.

When oil leaks from a well, it kills plants, birds, and other living things. If the well is in the ocean, the oil may spread over a large area. Then it kills sea life and ruins beaches.

It is only fair to think ahead to the people who will live after us. What will they want their environment to be like? In what condition should we leave the earth for them?

Iron mining does not make the land attractive.

Rusting cars do not make the land attractive, either.

Wise use of earth materials. Once we use coal, petroleum, or natural gas, they are gone. Then after they are all gone, what will we use to heat our homes? To run our automobiles? Fossil fuels took a very long time to form!

As we pump water out of the ground, water from rain and snow takes its place. But if we pump it out faster than it is replaced, what will happen?

When we mine aluminum or iron ore, there is that much less left in the ground. Then, if we throw away empty cans, what becomes of the aluminum or iron?

This does not mean that we should stop using materials from the earth. If we did that, we would not be able to live in comfort and health. We could not take trips, play sports, or even go to school!

The supplies of most earth materials will last for many years to come. But we must not waste them. The people who will live after us will need earth materials, too.

Whenever possible, we should use materials over and over again. For example, aluminum, iron, and glass can be melted again and used to make new things.

The wise use of materials is part of a good way of living. It is called *conservation.* What can you and your classmates do to help in conservation?

Ideas for REVIEW

- Pieces of rock, largest first, include boulders, cobbles, pebbles, sand grains, silt particles, and clay particles.

- Mud usually has particles of silt and clay.
- As a rule, the larger a rock particle is, the faster it sinks in water.
- Sediments deposited in water and in air are usually in layers.
- When there are several layers of sediment, the oldest layer is at the bottom.
- Within a layer of sediment the largest rock particles are usually at the bottom.
- As moving water slows down, much sediment sinks to the bottom.
- In places, sediments have become cemented or in some other way hardened into sedimentary rocks.
- Sediments and sedimentary rocks often give clues to what the earth was like in the past.
- In places, layers of sedimentary rocks have been raised and tilted by great forces inside the earth.
- Most fossils are parts of plants and animals that were buried in sediments, usually under water.
- Sedimentary rocks and substances found in them are very important in our lives.
- We should make wise use of sedimentary rocks and the materials we get from them.

TEST Your Understanding

Write the number of each question on a separate sheet of paper. Then write the letter of the best answer to the question. *Do not write in this book.*

1. Which size of rock particles sinks fastest in still water?

a. sand grains
b. silt particles
c. clay particles

2. When cemented together, which of these sediments forms conglomerate?

a. mud
b. pebbles
c. shells

3. Which of these substances most often fills the pores and other spaces in sedimentary bedrock?

a. natural gas
b. petroleum
c. water

4. Which of these sedimentary rocks may not have been formed from particles that came from bedrock?

a. limestone
b. sandstone
c. siltstone

5. Which of these substances would you be least likely to find in your drinking water?

a. air bubbles
b. mineral material
c. sediment

6. When pieces of rock of different sizes come loose from bedrock, what are the biggest ones called?

a. boulders
b. cobbles
c. pebbles

7. Which of these parts of dead fish were least likely to have become fossils?

a. bones
b. flesh
c. teeth

8. Which of these fuels is *not* a fossil fuel?

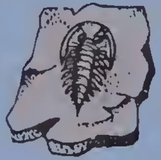
a. coal
b. petroleum
c. wood

9. How can it be that some layers of bedrock formed under water slant very steeply?

a. the layers were deposited that way
b. the water was moving fast
c. movements within the earth tilted the layers that way

10. Sometimes fossils of sea animals are found high up in mountains. When this happens, what is the most likely explanation?

a. the level of the water in the sea dropped
b. the bottom of the sea was pushed up
c. sea animals once lived on land



PROBLEMS—How Good a Geologic Detective Are You?

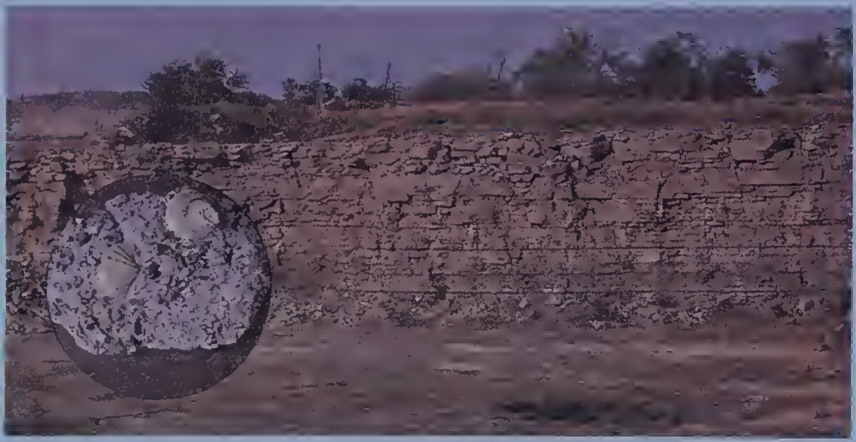
1. These pictures show layers of bedrock in four different places.

What do you think each place was like at the time the layers were being formed?

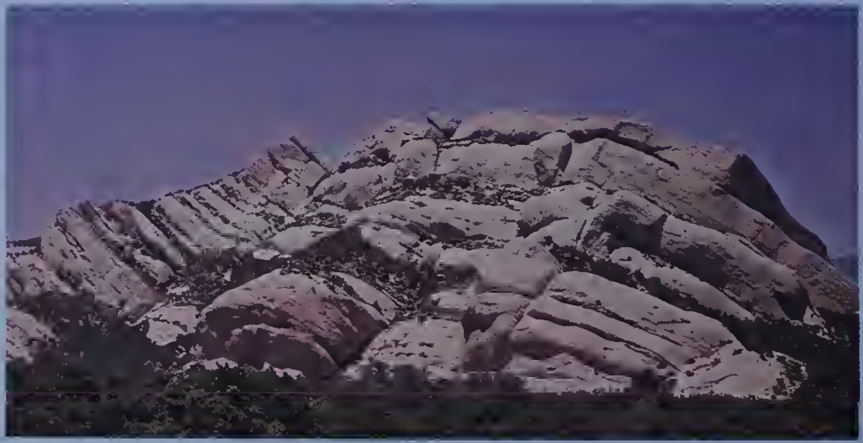
What can you infer has happened to the layers of rock since then?

You may find these words useful in answering these questions.

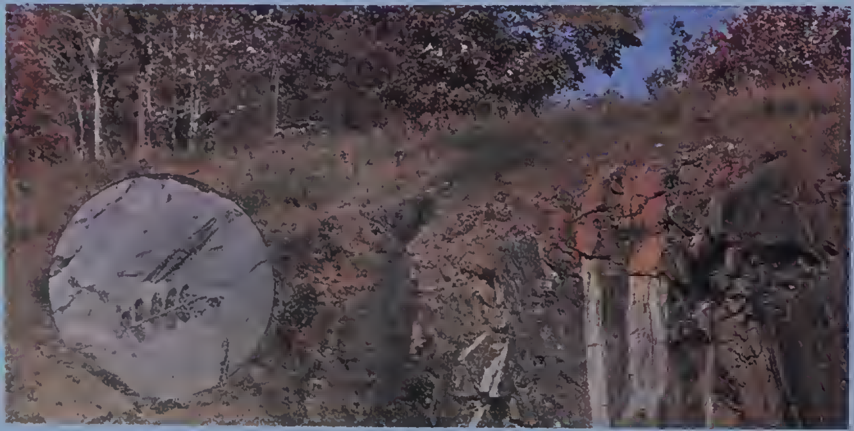
bend
force
forest
sea level
brachiopod
uplift
sediment
coral
river
gastropod
raise
tilt



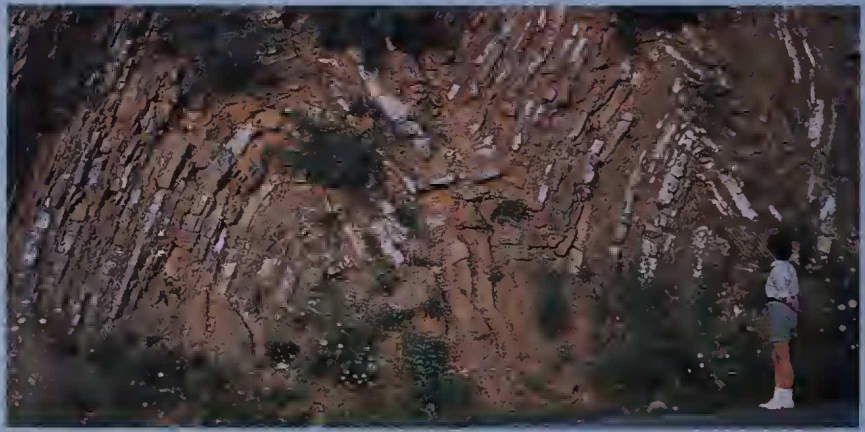
Limestone in a quarry. This rock contains many fossils of sea animals.



Sandstone in a desert. In these layers are found fossil wood and the bones and teeth of horses and camels.



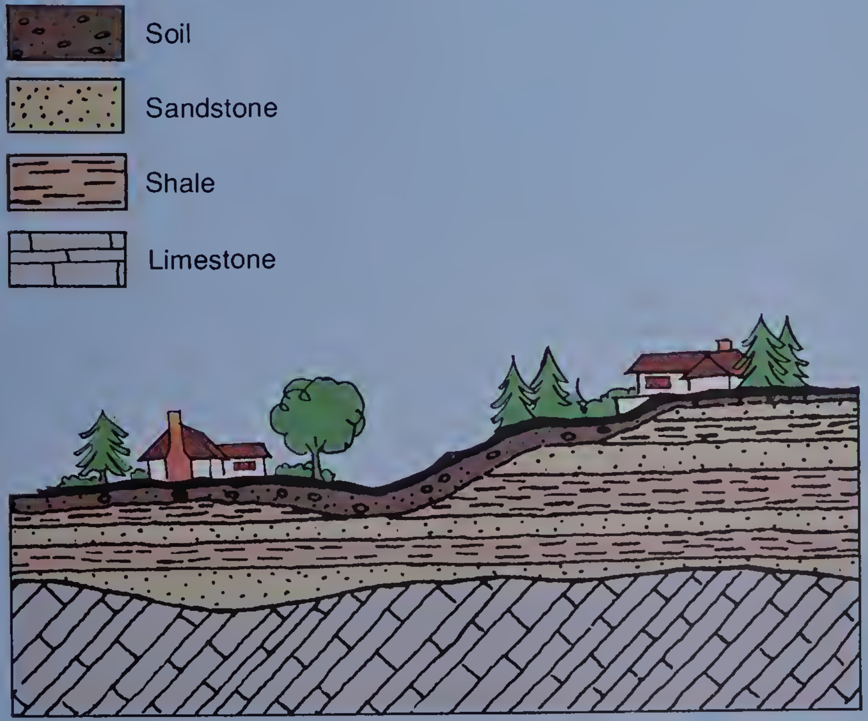
Shale, sandstone, and coal in a highway cut. These rocks contain fossils of ferns and other plants.



Shale and sandstone in a road cut. In places the layers of sandstone show ripple marks.

2. Suppose a deep cut is made in the earth for a new highway. It shows bedrock, with soil, trees and houses on top. The bedrock gives evidence of several geologic events. In what order do you think that these events took place?

- **a.** The layers of sediments which later formed shale and sandstone were deposited.
- **b.** The layers of limestone became slanted.
- **c.** The layers of sediment which later formed limestone were deposited.
- **d.** The layers of shale and sandstone were partly eroded.
- **e.** The layers of limestone were partly eroded.



FIND OUT on Your Own

Some scientists think that animals and plants like these lived about 140 million years ago.

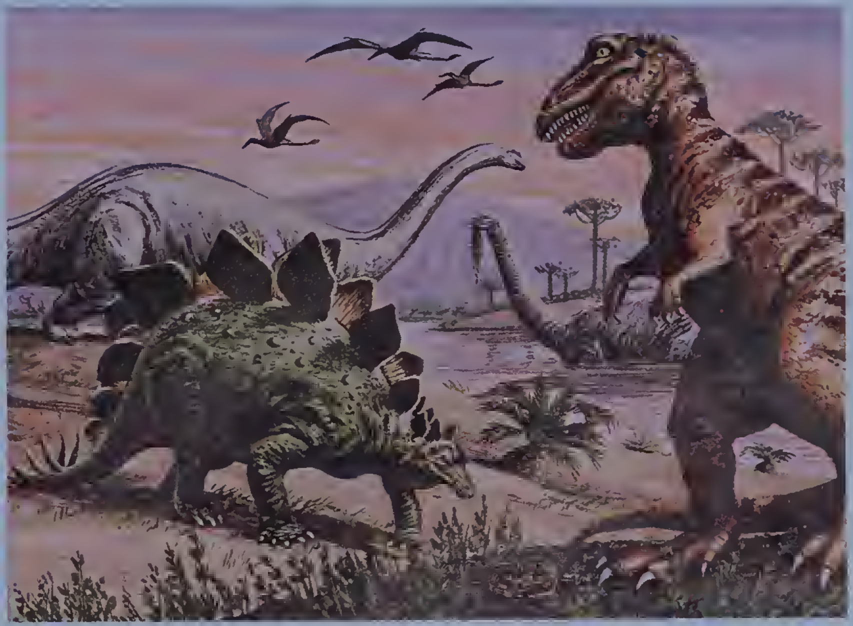
Try to find out more about them in the library. You might give a report on what you find. You may be able to answer some of these questions:

1. What clues in rocks show that animals and plants like these once lived on the earth? Where are these clues found?

2. How large were the biggest of these plants and animals? Were they all large?

3. What did the animals probably eat? How could you find out?

4. Are these kinds of plants and animals still living today? If so, where do they live?



3 Changes in Matter

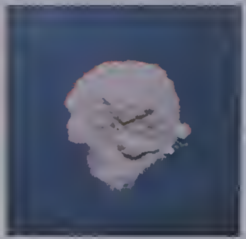
At home and at school—all around you—you may find many different kinds of matter. There are plastics, metals, liquids, powders, and gases. How are these things alike? How are they different? All matter is alike in two ways—it has mass and it takes up space. Even gases have mass and take up space. But matter may be different in many, many ways. It may be colored or colorless, shaped or shapeless. It may have a smell or have no smell. It can be a liquid, a gas, or a solid. And it can be visible or invisible.

There are likenesses and differences in the *properties* of matter. No two kinds of matter are alike in all of their properties.

SOMETHING TO TRY

Study some samples of table salt, white sand, and sugar. Without tasting them, try to find all the properties they have that are alike and those that are different. Keep a record of what you find.

- Put a few grains of each sample under a microscope or magnifying glass. Draw what you see.
- Can you see differences when the small bits are magnified?
- Can you tell any difference by rubbing a sample of each between your thumb and fingers?
- Does an equal amount of each material have the same mass?
- How much of each will dissolve in 250 mL of warm water?
- Do the samples smell differently?
- Are the samples all the same color?
- Are they equally shiny or dull?

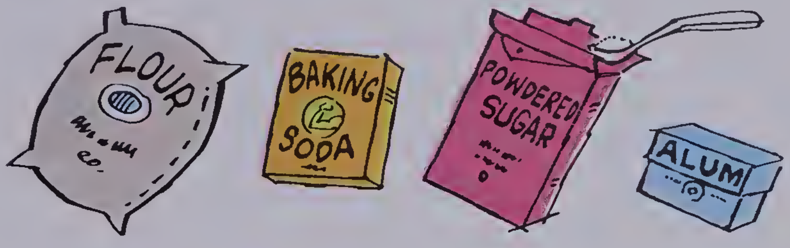


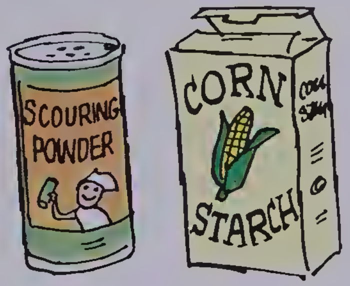
Physical properties. The things you have been observing are called *physical properties* of matter. Some physical properties that can be observed easily with your senses are shown on the chart below.

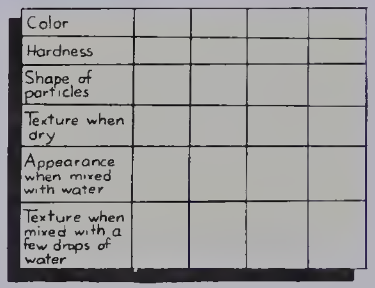
What senses did you use in studying the physical properties of salt, sugar, and sand?

OBSERVING PROPERTIES WITH YOUR SENSES	
SENSES USED	WHAT YOU OBSERVED
Seeing	color; size; shape; rough, smooth, dull, shiny, transparent, opaque, bouncy, liquid, solid, gas
Feeling, Touching, or Lifting	hard, soft, smooth, rough, cold, warm, stretchy, heavy for its size, light for its size
Hearing	ticks, rings, rattles, hisses, makes no sound
Smelling	smells; doesn't smell; smells: sweet, sour
Tasting	tastes: sweet, sour, bitter, cold, hot

Finding out about differences without tasting or smelling. Identifying unknown powders without smelling or tasting them can be fun and easy. What properties might help you name some unknown "kitchen powders"?







Color				
Hardness				
Shape of particles				
Texture when dry				
Appearance when mixed with water				
Texture when mixed with a few drops of water				

SOMETHING TO TRY

Find out how some kitchen powders are alike and different. Try some flour, baking soda, powdered sugar, scouring powder, alum, and corn starch.

Remember, do not taste or smell these powders but test each sample carefully in other ways. Then make a chart showing the properties of each. Some ideas you might use in your chart are shown above.

Are any of your powders too much alike to identify by physical properties alone?

JOBS Using Science

People who study the properties of matter are called *chemists*. They look at how matter is made up. They test different kinds of matter.

Chemists are interested in finding out about the smallest particles that make up a material. With this information, they are able to form many new products. Chemists are very important in the fields of drugs, dyes, and petroleum products.

Percy Julian is an example of a chemist who has invented many new products.

Much of his work centered around learning about the soy bean plant. He studied many of the chemicals that are found in this plant. He found out that one of these chemicals would be helpful in treating an eye disease. Another one would be helpful in treating arthritis. That chemical was used to produce the drug *cortisone*.

Dr. Julian continued his work until 1964 when he retired. During his long and productive career he developed more than 100 products.

SOME THINGS TO TRY

1. How much bounce? The ability of a material to bounce is a physical property. Some materials bounce better than others. A baseball, when it hits a bat, should bounce—but not too much.

Test the amount of bounce of different materials. Compare a Ping Pong ball, a tennis ball, a soft rubber ball, and a golf ball. Drop each from the same height. Measure and record the height of the first bounce. Which ball is made of a material having the greatest bounce?

2. How much stretch? The ability of a material to stretch is a physical property. Materials such as inner tubes from tires, rubber bands, and springs must be able to stretch over and over again.

Cut some rubber bands from an old inner tube. Make some 2 cm wide and some 4 cm wide.

How much is each sample stretched by loads of one, two, and three books? Does each sample return to its original size?

What happens if you leave a load of two or three books hanging on the sample overnight?

What would happen if the measurements were made after the sample has been resting in the hot sun? Test your ideas.

Hard or soft? Hardness is another physical property of matter. Often it is important that a material not be too soft or too hard. For example, you would choose a soft lead pencil if you wanted to make a heavy, dark line. You would choose a harder lead pencil for a thin, light line.

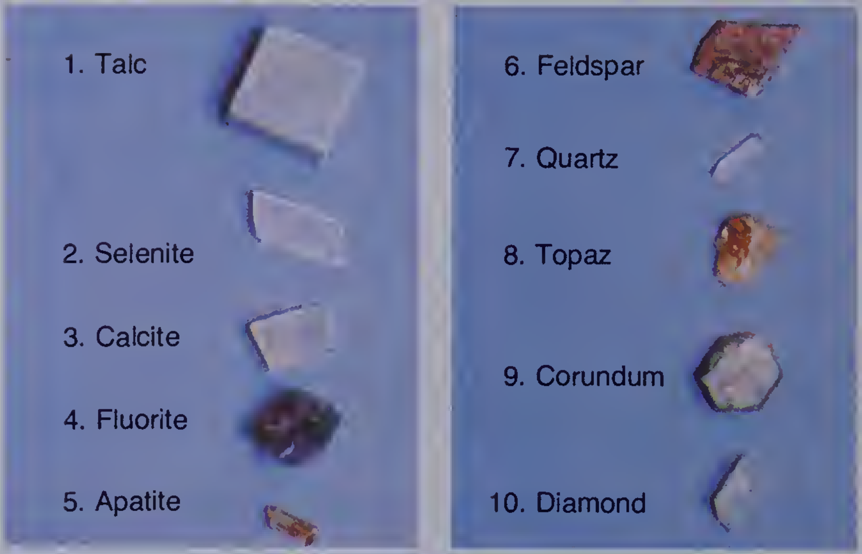
We use many kinds of wood. Some are so hard that it is difficult to drive a nail into them. Others are so soft that they can be dented by pushing on them with your thumbnail.

The scratch test. One way you can find the hardness of a material is to use the scratch test. One thing is harder than another when it can scratch the other material. For example, a piece of hardwood can be used to scratch a piece of softer wood.

Scratch tests are probably most useful in finding the hardness of minerals. The property of hardness often can help us identify unknown minerals. Does a mineral scratch a piece of glass? Does a mineral scratch a coin? Or, does it scratch another mineral of known hardness?

The chart below shows 10 minerals in order from softest to hardest. From the chart, predict whether quartz will scratch calcite. Which minerals will calcite scratch?

SCALE OF HARDNESS OF MINERALS



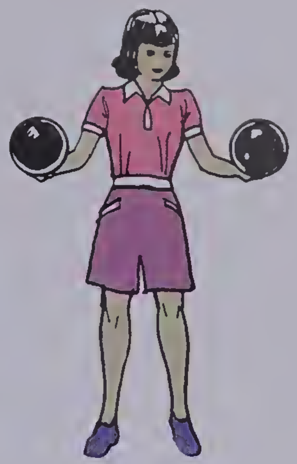
SOMETHING TO TRY

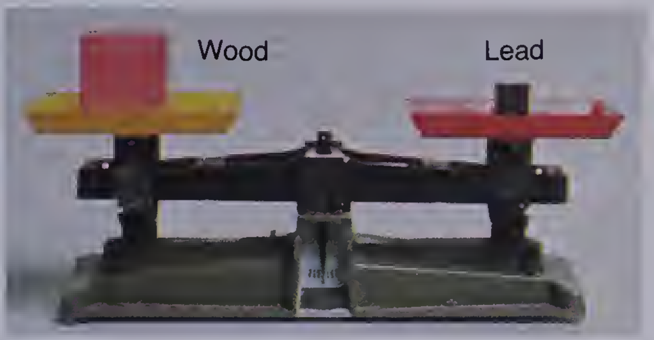
Test the hardness of some common materials. Try a coin, an iron nail, an aluminum can, and a piece of brick, chalk, or a clay flower pot. List the materials you tested from least hard to hardest.

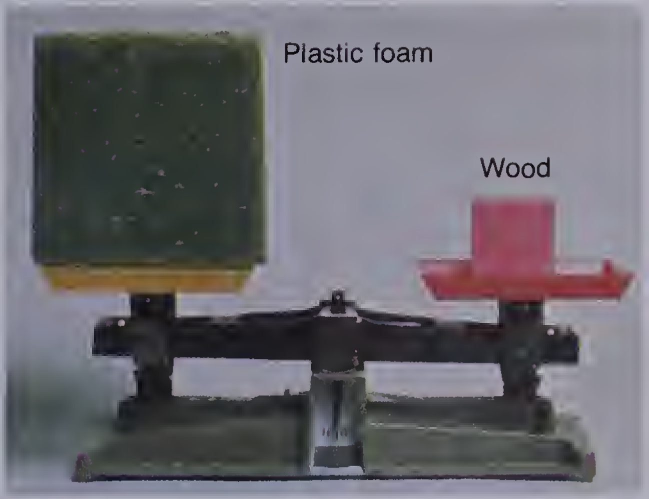
Mass. *Mass* is the amount of matter in something. The mass of something is an important property. A baseball player may choose a light or a heavy bat. The heavy bat has more mass.

In bowling, the mass of the ball may affect how well the bowler does.

The mass of a bat or a bowling ball depends partly on the size. It also depends on the kind of material the bat or ball is made of.







Volume. *Volume* is the amount of space something takes up. Look at the pieces of lead, wood, and plastic foam on the balances. Which piece takes up the most space? Which has the greatest volume? Which has the least volume?

Though the pieces have different volumes, they all have the same mass. How can you tell the masses are the same?

Suppose you had pieces of lead and plastic foam that had the same volume. Which would have the greater mass?

SOMETHING TO TRY

How do you measure the volume of a rock? One way is by putting it in water. As the rock is lowered into water, the water level rises. The amount the water rises is the amount of space the rock takes up. This is the volume of the rock.

Use a small, narrow, 250 mL-jar. Put a piece of tape along one side, from top to bottom. You can mark a scale for measuring volume on this tape.

A 250 mL-jar has a volume of 250 cubic centimetres, or 250 cm^3. So, if you mark 16 even spaces along your tape, each should stand for about 15 cm^3.

Now fill the jar about half full with water. Make sure the water level is even with one of the marks on the tape.

Tie a string around a small stone. Lower the stone all the way into the water.

Count how many marks the water rises. This is a measure of the stone's volume in cubic centimetres.

Suppose the water is at the seventh mark from the bottom. After lowering a stone, the water rises to the tenth mark. What would the volume of the stone be?

COIN PROBLEMS

1. How many one-cent coins do you think it takes to make a kilogram?

2. How would you measure the volume of a kilogram of these coins?

3. Knowing the volume of a kilogram of coins, predict the volume of two kilograms.

Some Physical Changes LESSON 3

These girls and boys are working with clay, wire, wood, copper, and paper. In most cases there is some change in the shape of the materials. When something changes shape, the change is called a *physical change*. What physical changes are shown below?

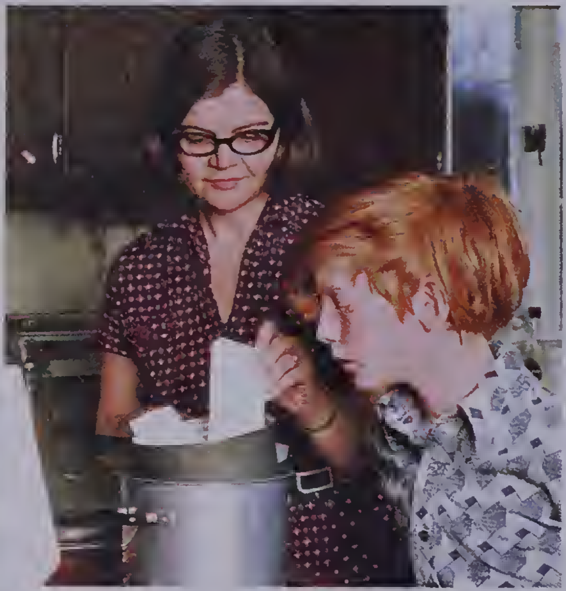
Changes in shape. When you hammer a piece of copper into a different shape, you cause a physical change. When you stretch a rubber band, you change its shape. When you freeze water, you change its shape. When you make a clay model, you change the clay's shape.

How often do you change the shape of something? Think about all the physical changes you may have caused today.

Melting and hardening. It is hard to change the shape of solid wax. To make candles, the blocks of wax first must be melted, or changed to a liquid. Melting is a physical change. "Solid" and "liquid" describe physical properties.

As the liquid wax cools, it becomes a solid. This is another physical change.

What other physical properties change when making wax into candles? What physical properties stay the same?

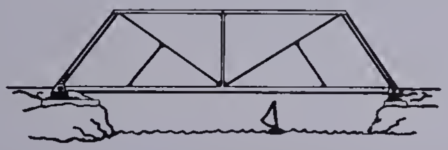


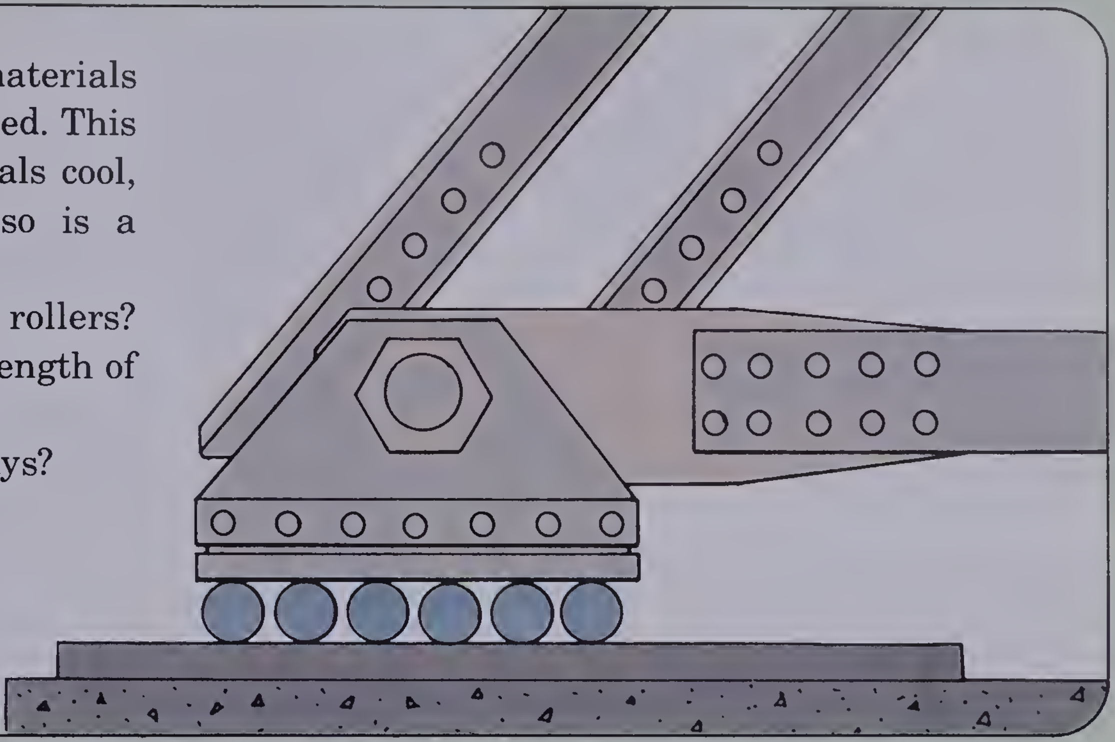
Liquid to gas. When a liquid boils, it may *evaporate*. It becomes a gas. This change is a physical change. For example, when water boils, it changes from colorless liquid to a gas that can not be seen. What do you think will happen when the gas is cooled?

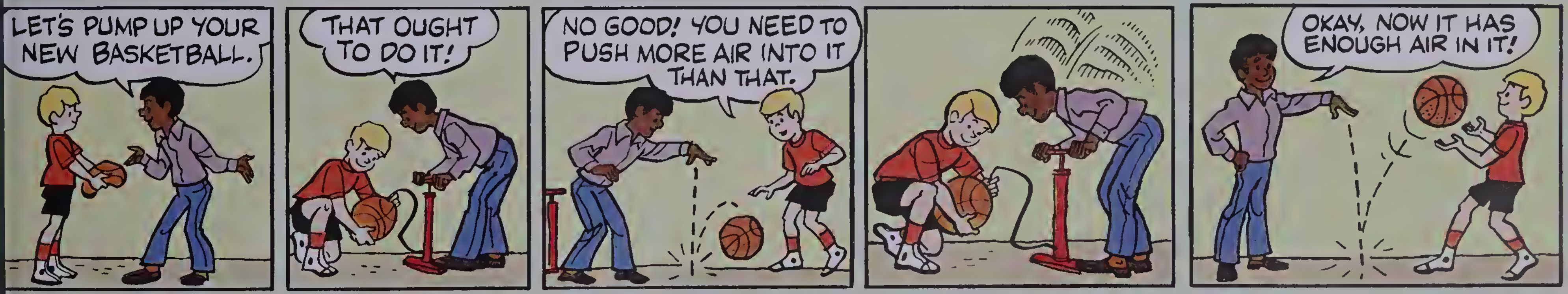
Expansion and contraction. Most materials get larger, or *expand,* when they are heated. This is a physical change. When most materials cool, they get smaller, or *contract.* This also is a physical change.

Why do you suppose the bridge is on rollers? What do you think would happen to the length of the bridge on a hot summer day?

What other objects expand on warm days?

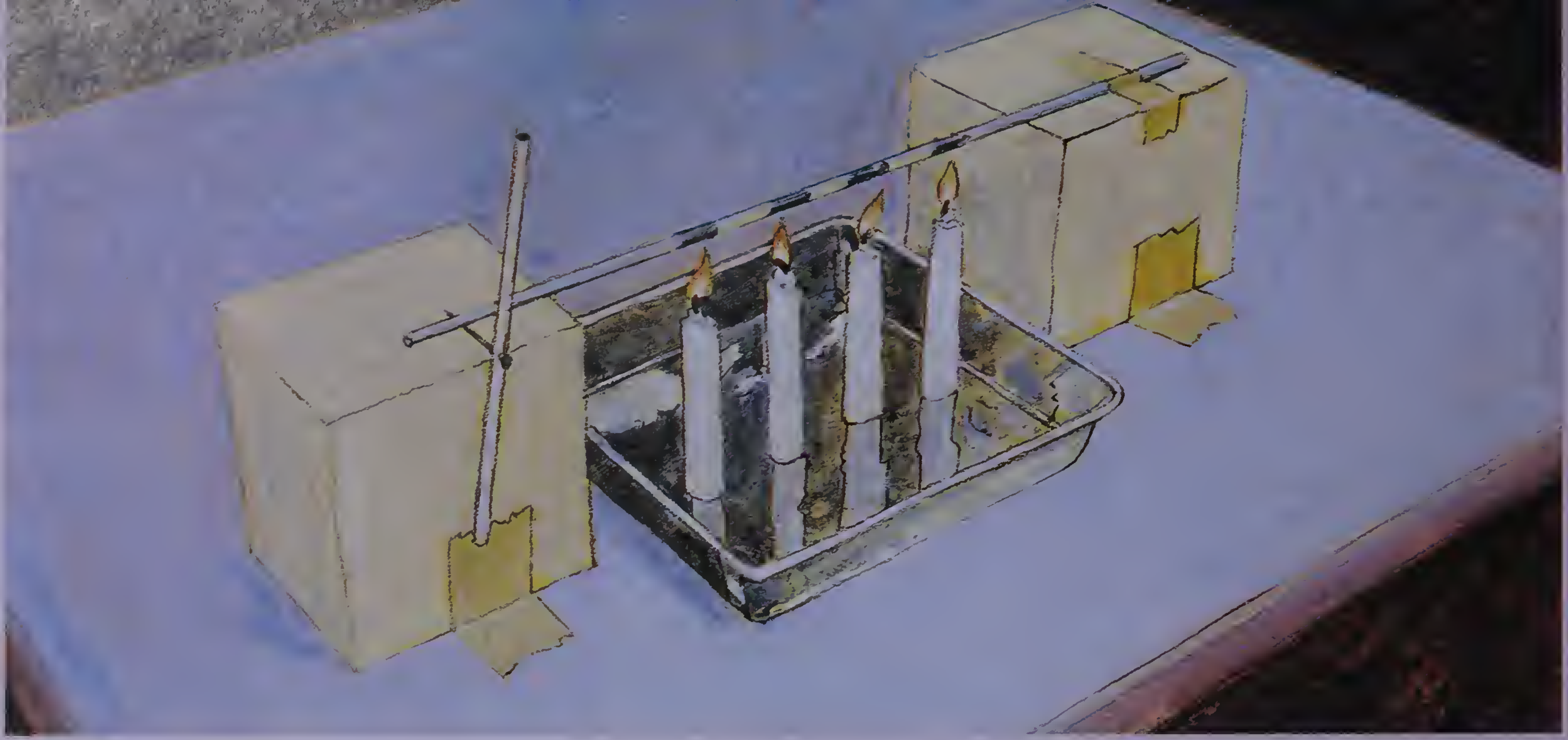





LET'S PUMP UP YOUR NEW BASKETBALL.
THAT OUGHT TO DO IT!
NO GOOD! YOU NEED TO PUSH MORE AIR INTO IT THAN THAT.
OKAY, NOW IT HAS ENOUGH AIR IN IT!

Compression. Gary caused a physical change by putting more air into the ball. Did he change the volume of the ball? The mass of the ball?

When more and more air is pushed into a space, the air becomes *compressed.* What other physical properties change as the air is compressed?



SOMETHING TO TRY

What takes place when a bridge expands may be shown with a model.

Use a straight metal rod that is about 45 cm long. Place its ends on two similar, smooth, wooden blocks. Tape the blocks in place. Now tape one end of the rod tightly to one of the blocks.

Then cut a plastic straw in half. Stick a small nail through the middle of one of the halves. This will serve as a pointer. Set the nail on the other block. Rest that end of the metal rod on it.

Put a metal pan under the rod. Then stand four short candles in it. Be sure to place them in a row under the rod. Now light them. What happens to the pointer? Why?

What do you predict will happen to the pointer after the candles are blown out? Blow out the candles. Was your prediction correct?

Safety Note: *Be sure an adult is present when you do this activity.*

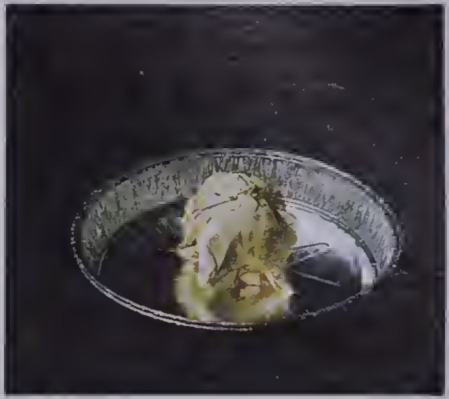
Chemical Properties and Chemical Change

LESSON 4

There are tests that can be done to observe the *chemical properties* of matter. These tests show if something will be chemically changed under certain conditions. In a chemical test, the material may change into something different. Changes which make new materials are called *chemical changes*.

Burning. Most paper will burn quite easily. The ability to burn is a chemical property of paper. Burning is a chemical change.

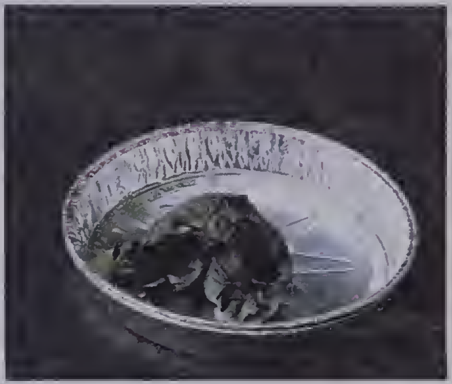
When a chemical change happens, one or more new materials may result. Some evidences of chemical changes are changes in color, odor, or mass. How many of these evidences of chemical change can you see when you burn paper?



1

2

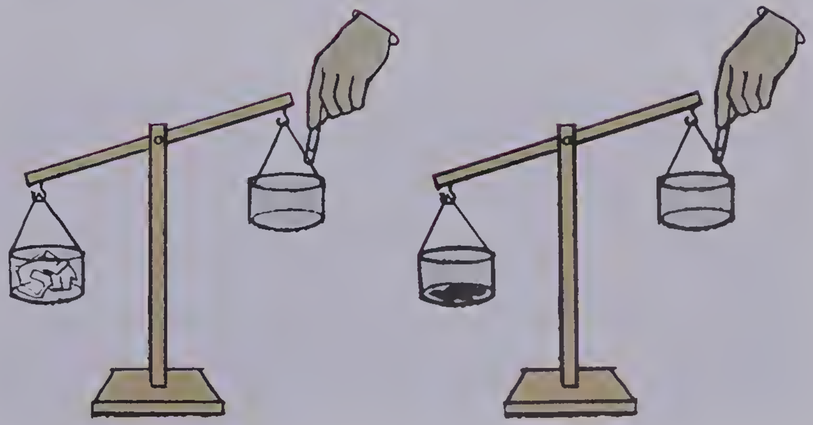
3



4

SOMETHING TO TRY

With your teacher's help, burn a piece of paper in a pie pan, as shown. Record all the evidence of change you see. If you have a balance scale, you may be able to tell whether the mass changes. Does a piece of paper gain or lose mass when it is burned? Can you explain why?



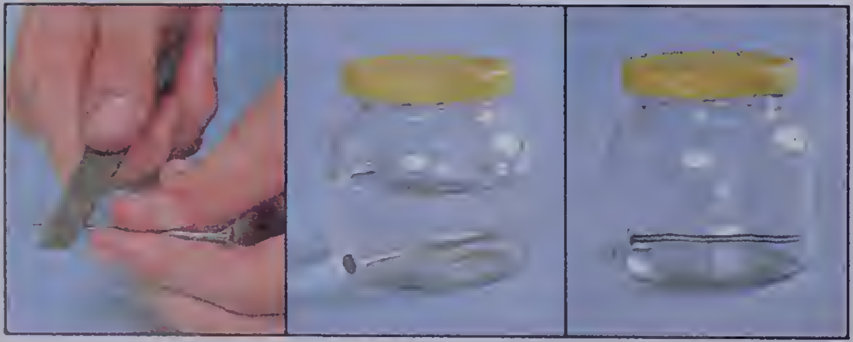
Rusting. One chemical property of iron is that it will rust. Rust is not the same material as iron. It is chemically different. Iron that is rusting is going through a chemical change. Rust contains iron and oxygen, chemically joined. Rusting, like many other chemical changes, most often happens naturally.

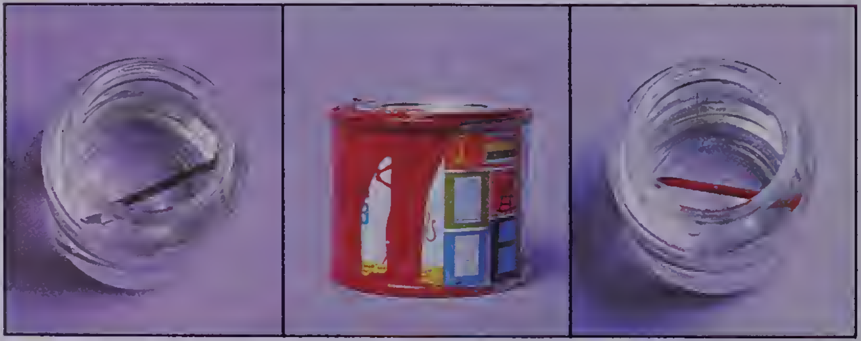
Many people have experimented with ways to prevent rusting. Iron objects are sometimes coated with paint, plastic, or oil. But in time, some rust begins to appear.

SOME EXPERIMENTS

Here are two special problems you can investigate. Each problem calls for a separate experiment. When you set up your experiments, be sure that all conditions are the same except the one you are investigating.

- Does water help cause rusting?
- Does paint help stop rusting?





Living things can cause chemical changes. By themselves, *yeast* organisms are too small to be seen without a microscope. Thousands are packaged together and sold in powder form. Many people do not know they are buying packages of living things. They think of the yeast as a sort of chemical powder. But it is not. It is a package of hundreds of tiny living organisms.

Yeast organisms produce important chemical changes in their environment. People have found many ways of using these chemical changes.

Yeast organisms are used in baking. When put in water that has sugar or flour, the yeast begin to grow. If this mixture is kept warm—about 37°C—the yeast multiply rapidly. They also take in water and liquids.

One sign of chemical change caused by yeast is the odor of *alcohol*. Alcohol is a liquid produced by yeast. Another sign of chemical change is the foaming and bubbling of the mixture. This is due to carbon dioxide gas, also produced by yeast.

Yeast growing and multiplying

SOMETHING TO DO

Study some actively growing yeast. Observe the evidences of chemical changes that they produce.

Shake about one-half pack of powdered yeast into a clear container. Add 15 mL of sugar and 100 mL of warm water. Set this mixture in a warm place. Watch it for about 10 to 15 minutes. Record any evidence of chemical change.

Now divide the mixture into two parts. Put one part in a very cold place. Keep the other in a very warm place. After 15 minutes compare the mixtures. Does the cooler temperature speed up or slow down the chemical changes taking place?

Acids and bases. Some chemicals are classified as *acids* or *bases*. There are acids and bases right in your own home. In fact, some mild acids are in the foods you eat. Any food with a sour flavor contains some acid. Many household cleaning products contain bases.

Litmus tests. To see whether common materials contain acid, you can use strips of blue *litmus paper*. Touch the blue litmus to a moist sample of the material. If the material contains acid, the litmus will turn pink.

To see if common household materials are bases, use a strip of pink litmus. It will turn blue when touched to a moist base.

What if neither the blue nor pink litmus changes color? How would you classify the material? The material is classified as chemically *neutral*. It is neither an acid nor a base.

ACID TURNS BLUE TO PINK

BASE TURNS PINK TO BLUE

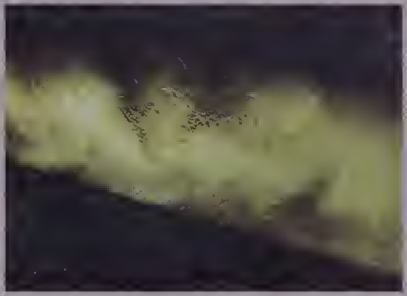
SOMETHING TO DO

Using blue and pink litmus, test some common materials. Test things such as soaps, juices, soft drinks, "kitchen powders," and toothpastes. Are they bases, acids, or neutral?

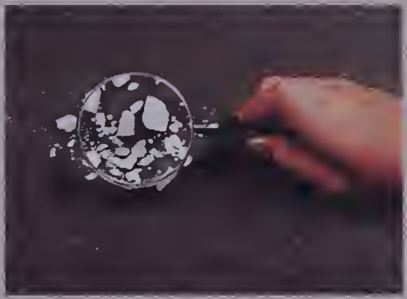
Safety Note: *Never taste anything that you are not sure is safe!*

Some materials, such as pencil lead and chalk, are useful because tiny *particles,* or bits, rub off easily. Why is this a useful property?

Bits of chalk dust are so small they settle slowly in the air. They seem to disappear. But a beam of light makes the dust visible. Why?



Some things, such as sugar cubes, can be broken into smaller and smaller bits. What do these bits look like when they are magnified?



Here, bits of sugar have disappeared in water. Can you still taste the sugar? Explain your answer. How can you find out if you are right?

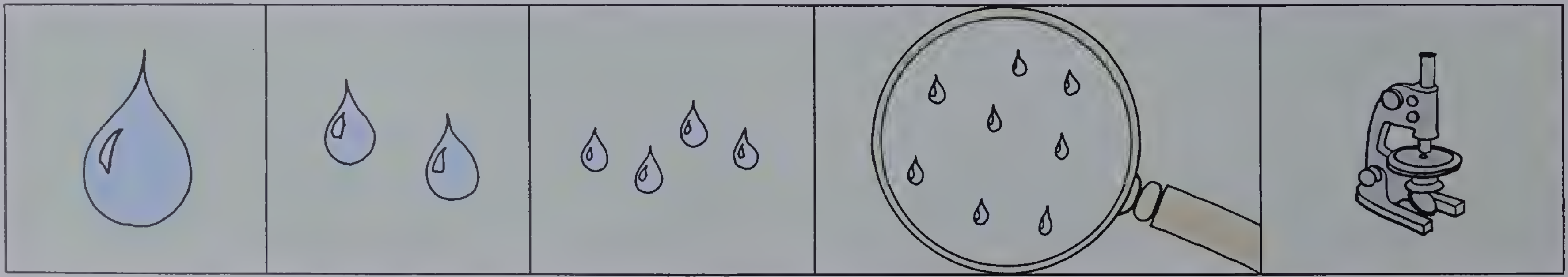
Visible to invisible. From observation we know that visible bits of matter may be made smaller and smaller. In fact, they may become so small that they cannot be seen! But, as with the sugar and the chalk, we can prove that the tiny bits of matter are still there.

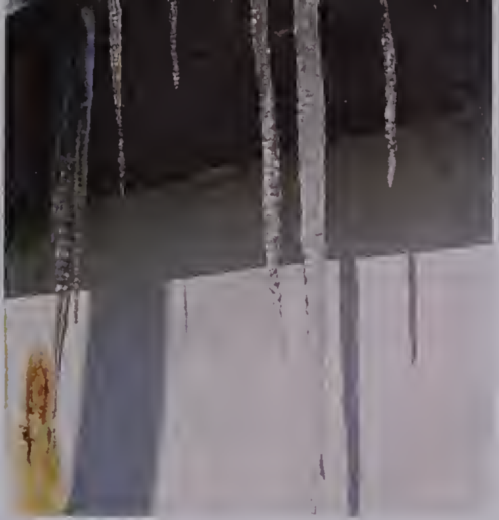
Scientists infer that all matter is made of invisible particles. In large numbers, these particles make up the things in the world around us.

What are molecules and atoms? You may have heard of *molecules* and *atoms,* but perhaps you are not quite sure of what they are. All matter is made of tiny particles. What tiny particles can we correctly call molecules? And what particles can we call atoms?

Molecules and water. Let's begin by looking at one of the most common substances on earth—water. Suppose you could take one tiny drop of water and keep breaking it into smaller and smaller particles. You would finally get to the smallest possible particle of water. This particle that still has the properties of water is a molecule of water.

You cannot see a single molecule of water, nor a molecule of sugar or oil. A molecule of any substance is too small to see, even with a very good microscope.





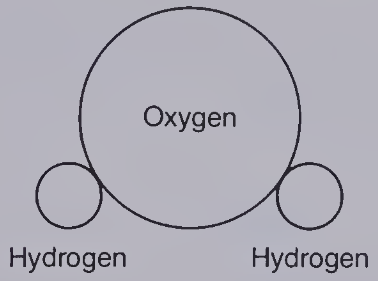
Properties of water molecules. Can you guess what the properties of water molecules would be if you tested them? Suppose you gathered together enough of these to look at. You would see a colorless, odorless, tasteless substance. At room temperature it would be mostly a liquid. Below 0°C it most likely would be a solid. Above 100°C it most likely would be a gas. The water would dissolve many things such as sugar and salt. But it would not dissolve others, such as sand.

In other words, molecules of water would have all the properties belonging to the material called water. No other kind of molecules on earth have exactly the same set of properties. And no other substance on earth is made of the same kind of molecule.

There is nothing smaller than a molecule of water that still has the properties of water. But can water molecules be broken into smaller bits? If so, what would these smaller bits be called?

Building blocks of water molecules. All water molecules are made of even smaller bits called atoms. Each water molecule is made of *hydrogen* and *oxygen* atoms. There are two hydrogen atoms and one oxygen atom. A short way to write this is H_2O. Only when these atoms are chemically joined together do we have water molecules.

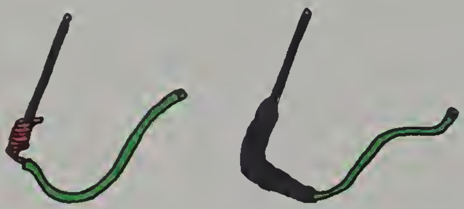
At a certain temperature, ice changes from a solid to a liquid. When heated to a higher temperature, the same water changes from a liquid to a gas. It goes through these physical changes without any change in its molecules. The molecules of water always have two atoms of hydrogen and one atom of oxygen.



Breaking up water molecules. It is possible to break up molecules of water. This can be done by using an electric current. When a current passes through water it causes a chemical change. This change separates two substances—oxygen and hydrogen. The hydrogen and oxygen are no longer chemically joined. Each is a separate substance with different properties. They are unlike the original substance—water.

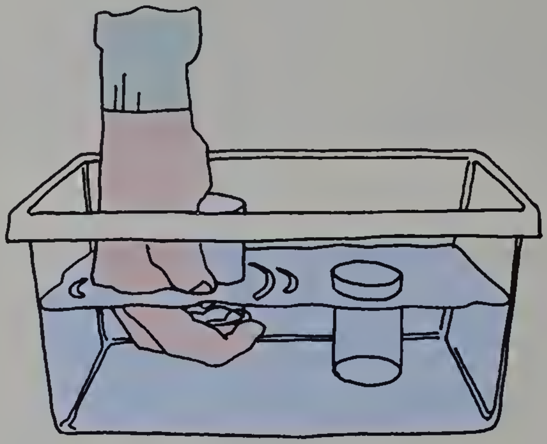
SOMETHING TO TRY

You can separate water into oxygen and hydrogen with an electric current. Wrap the bare ends of two pieces of insulated wire around the ends of two pencil leads as shown. The pencil leads should each be about 4 cm long. Cover all the bare wire with electrical tape. But do not cover the remaining part of the pencil lead.

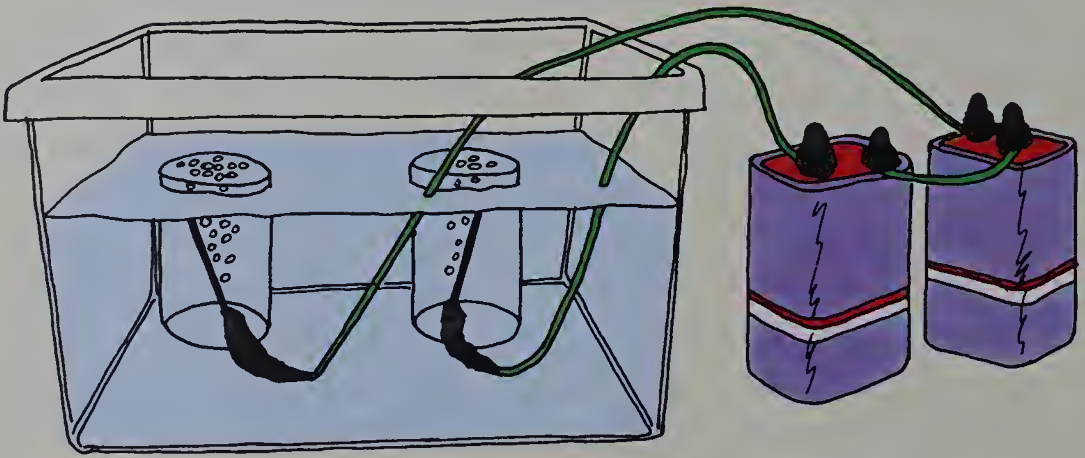


Next, mix about 15 mL of Epsom salt in 1 L of water. Stir thoroughly. This solution is a better conductor of electricity than plain water.

Fill two small bottles with this solution. Hold your fingers over their mouths and place them upside down in the solution.



Then, carefully set them over the pencil leads as shown in the drawing. Connect the other ends of the wires to two 6-volt batteries connected as shown.

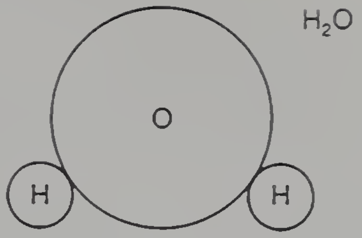


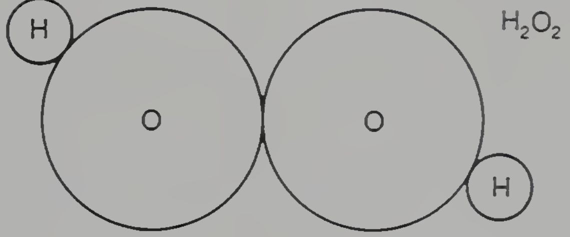
You should see bubbles of gas rise and collect in each bottle. When the first bottle is filled with gas, cover the mouth with your fingers and remove it. Replace this bottle with another one.

Test the gas in the first bottle with a glowing wood splint. If the splint bursts into a bright flame, the gas is oxygen. If the gas makes a tiny "pop," it is hydrogen. Test the gas in the other bottle when it is full.

About two bottles of one gas will be produced to every one of the other. Which gas are you getting more of? From the *formula* for water (H_2O), can you explain these results?

Safety Note: *Be sure an adult is present when you do this activity.*





Other molecules and their atoms. There are hundreds of thousands of different substances in the world. There are only a little over 100 kinds of atoms. Yet all of the many different substances are made from one or more of the atoms.

You have learned that water molecules have two kinds of atoms—hydrogen and oxygen. These atoms are chemically joined together. The formula for water is H_2O. A common bleach called *hydrogen peroxide* also has hydrogen and oxygen atoms chemically joined. The formula for hydrogen peroxide is H_2O_2.

The properties of water and hydrogen peroxide are very, very different. However, they are made of the same two kinds of atoms. From the formula, tell how their molecules differ.

SOMETHING TO DO

Compare the chemical properties of water and hydrogen peroxide.

At a drugstore, purchase a bottle of 3% hydrogen peroxide solution. Pour a small amount of it into a test tube. Into another test tube, pour about the same amount of water. Then, to each of these add a pinch of dry, powdered yeast.

With a glowing wood splint test any gas that is produced. What evidence is there that the gases are the same or different?

C_2H_5OH

Grain alcohol

$C_{12}H_{22}O_{11}$

Cane sugar

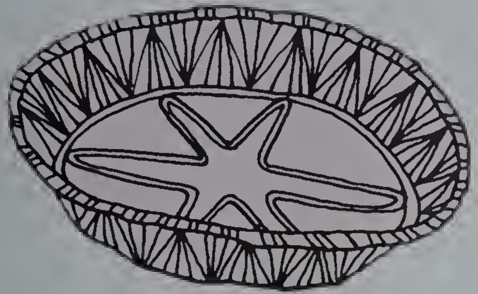
CH_3COOH

Vinegar

Many things with different properties are made of atoms of hydrogen, oxygen, and *carbon*. Look at the formula for a molecule of grain alcohol above. Then look at the ones for vinegar and cane sugar. All of these are made of the same three kinds of atoms. From looking at the formulas, how are their molecules different? How is sugar different from vinegar? How is sugar different from alcohol? How is alcohol different from vinegar?

Many things have the same kinds of atoms. But the atoms are joined in different ways. Each way makes a molecule with properties different from all other molecules. No two kinds of molecules ever have the same properties—even those with the same kinds of atoms.

Again look at the formulas. Can you tell how many atoms there are in each molecule? Which molecule has the largest number of atoms?

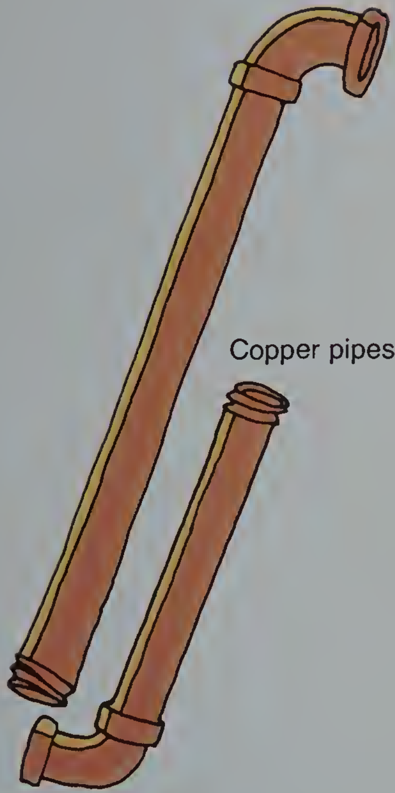

Aluminum pie pan

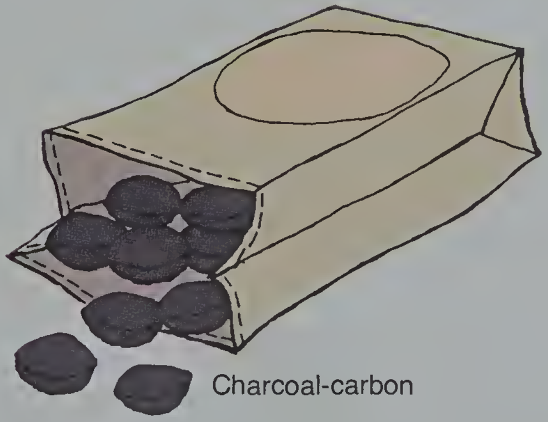
Oxygen tank

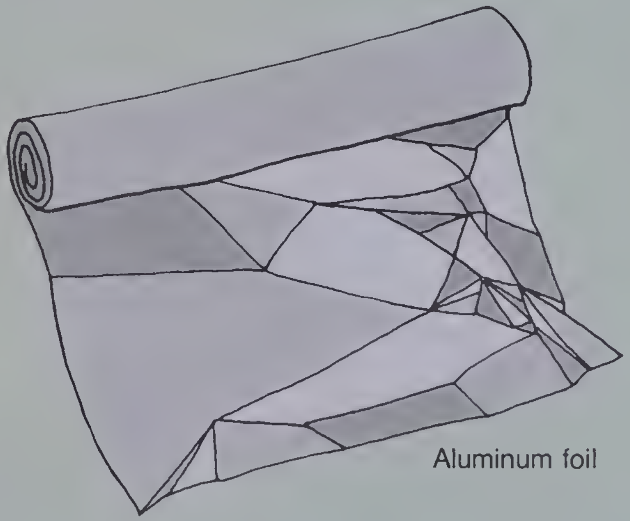
Compounds and elements. All of the substances such as water, hydrogen peroxide, and sugar belong to a group called *compounds.* A compound is any material that has more than one kind of atom chemically joined together. What materials are not compounds?

Materials with molecules that have only one kind of atom are not compounds. They are called *elements*. Do you know of any such materials?

Copper, aluminum, carbon, oxygen, and hydrogen are all examples of elements. A pipe made of pure copper contains only atoms of copper. A pan made of pure aluminum contains only atoms of aluminum. Molecules of oxygen contain only oxygen atoms. A piece of pure black charcoal contains only atoms of carbon.


Copper pipes


Charcoal-carbon


Aluminum foil

Ideas for REVIEW

- All matter has mass and takes up space.
- The three states of matter are solid, liquid, and gas.
- No two kinds of matter are alike in all of their properties.
- Your senses can help you observe the physical and chemical properties of matter.
- Color, hardness, shape, texture, and odor are some of the physical properties of matter.
- When a material changes shape, the change is called a physical change.
- Most materials expand when they are heated.
- Most materials contract when they are cooled.
- Mass is the amount of matter in something.
- Volume is the amount of space something takes up.
- Objects with the same mass may have different volumes.
- Changes which produce new materials are called chemical changes.
- You can find out if a substance is an acid, base, or neutral by testing it with litmus paper.
- Scientists infer that all matter is made up of invisible particles.

TEST Your Understanding

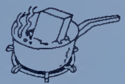
A. On a piece of paper, write the numbers 1 to 8. Next to each number, write the word "physical" or "chemical" to make each sentence correct. *Do not write in this book.*

1. Burning a piece of paper is an example of a _____ change.

2. Cutting a rope in half is an example of a _____ change.

3. Stretching a piece of rubber is an example of a _____ change.

4. Melting a piece of wax is an example of a _____ change.



5. Yeast organisms producing alcohol is an example of a _____ change.

6. A piece of metal expanding is an example of a _____ change.

7. A wagon that is rusting is an example of a _____ change.

8. Baking a cake is an example of a _____ change.

B. On your paper, write the word that makes each sentence correct.

9. Particles that are even smaller than molecules are called _____ .

10. Materials that have molecules that contain only one kind of atom are called _____ .

11. A _____ is any material which has more than one kind of element chemically joined.

12. The smallest particle that still has the properties of water is called a _____ of water.

C. On your paper, write the best answer to each of the following questions.

13. Which of these materials is a compound?

salt copper oxygen

14. Which of these materials is an element?

sugar aluminum salt

15. Which molecule has twelve atoms of carbon?

C_2H_5OH $C_{12}H_{22}O_{11}$ CH_3COOH

PROBLEMS

1. When both are at room temperature, the head of the screw will just pass through the screw eye. When the screw is heated, what physical change will take place? Will the screw be able to pass through the screw eye? What will happen when the screw eye also is heated? Test your ideas.

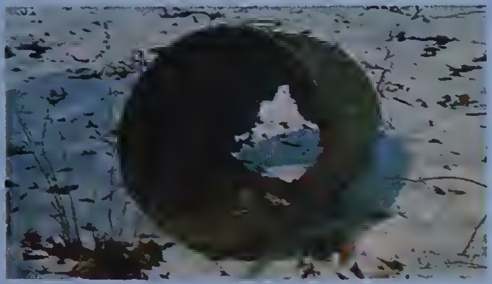
2. Jo burned a candle under a dry jar. The candle burned as long as it had enough oxygen. Then it went out. She noticed small drops of a clear liquid had formed inside the jar. What was this liquid?

She also noticed that the wick of the candle was now covered with a black substance. What might this substance be?

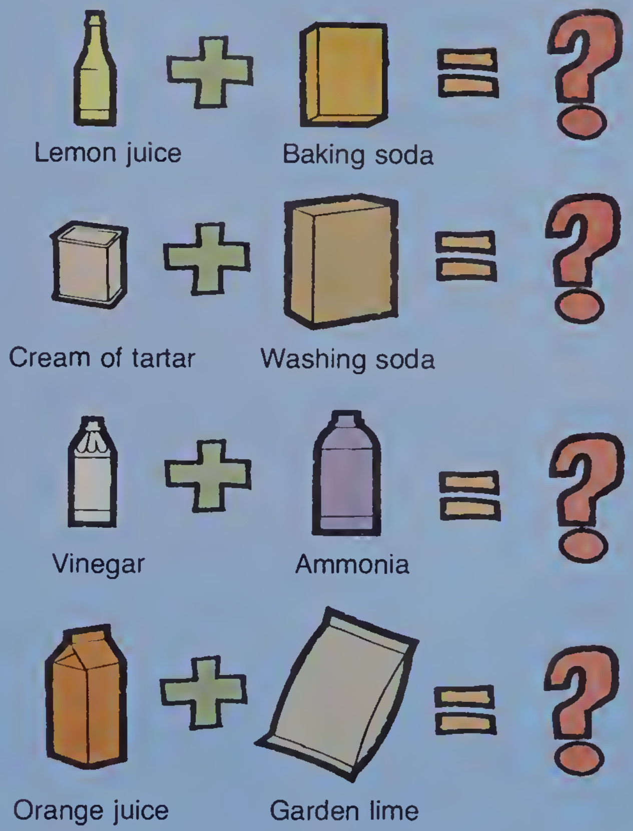
The liquid in the jar and the black substance on the wick may be evidence of the presence of what three elements?

3. Much of the iron ore we use is a compound called iron oxide. When this ore is heated in a blast furnace a chemical change takes place. The two elements, iron and oxygen, are separated. Is this separation usually permanent? Why?

What evidence is there that some of the earth's iron is going through a cycle of chemical change?



FIND OUT on Your Own



See if you can neutralize some common household acids by adding some common bases. First test the material with blue litmus paper to see if it is an acid. Then gradually add small amounts of a base such as baking soda or household ammonia. Do this until the original material is neutral.

If you add too much base, what color will the litmus turn? If you add the right amount to make a completely neutral mixture, what color will the litmus be?

4 Your Nutrition and Other Needs

Your body needs food, water, and oxygen. Food is needed for *nutrition*. Good nutrition means eating the foods your body needs. The things you eat and drink make up your *diet*.

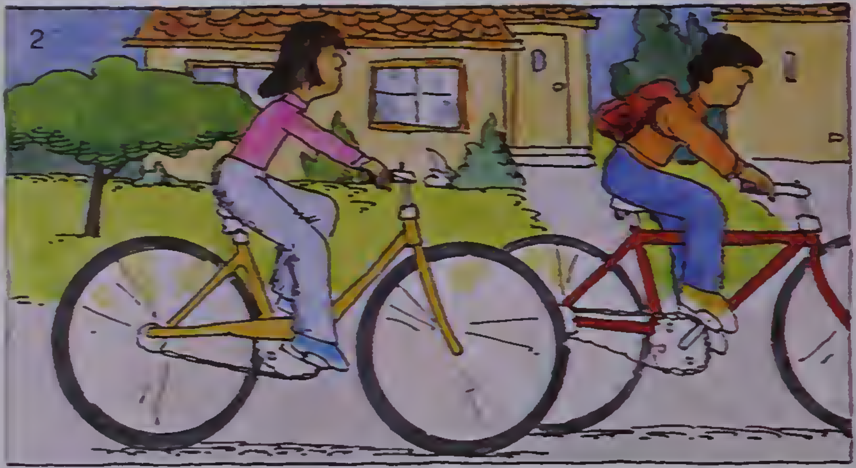
Think about your diet. What things do you eat and drink? Are all of these things good for you? Could some be bad for you? How can you find out about the foods you eat?

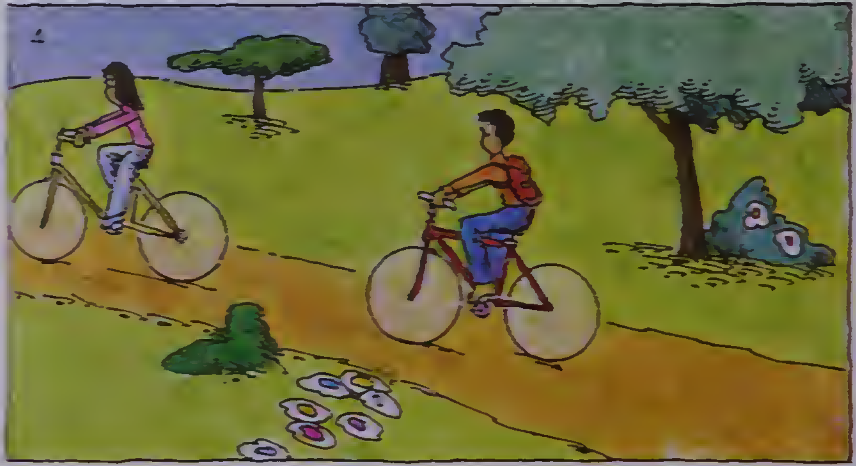
Food for Energy LESSON 1

You need *energy* to run, write, and even to talk. You need it to breathe and to use the food you eat. You even need it for your blood to move through your body. Where do you get all the energy you need?

Food has stored energy. Some foods have more than others. Foods that have *carbohydrates* and *fats* have a lot of stored energy.

Carbohydrates. Your body needs the energy from carbohydrates to move, grow, and keep warm. Most of the carbohydrates people eat come from green plants that are rich in *sugar* and *starch*. Green plants make these carbohydrates, using energy from the sun. Can you think of any foods that you eat that come from green plants? Make a list of them.





SOME THINGS TO TRY

Starch is found in many foods and even in some nonfoods. You probably can find a box labeled "Cornstarch" in your house. You may even find a box labeled "Laundry Starch." Most likely all the starch you find was made by green plants.

How can we find out if something has starch? You can make a test by using iodine. When iodine is added to something that has starch, a blue-black color change is produced. If something has no starch, the color will not change.

1. To find out how the starch test works, fill two paper cups half full with water. Then put about 5 g of cornstarch in one cup and stir. Do not put cornstarch in the other cup. This cup will be your control. The control cup shows what happens when starch is not there. Now put two drops of iodine in each cup.

Safety Note: *Iodine is a poison. Do not get it near your eyes or mouth.*

What happens in the cup with cornstarch? What happens in the control cup? The color change always shows that there is starch in something.

2. Get some samples of different foods and nonfoods. Put each sample in a paper cup. Add some iodine to each cup. Record what you find out.

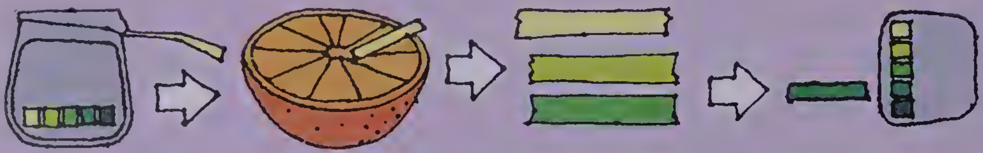
	Potato	Rice	Apple	Cheese	Bread
Color					
Starch					
No Starch					

Sugar. Sugar is another carbohydrate. How can you tell if a food has sugar? Most often, foods that taste sweet have sugar.

There are different kinds of sugars. The ones your body can use easily are called *simple sugars*. Ripe fruits have simple sugars. The sap of some trees also have simple sugars.

Table sugar is another kind of sugar. It is called a *complex sugar*. Your body must change this complex sugar to a simple sugar before your cells can make use of it.

Table sugar often is used to make foods taste sweet. Can you think of any foods that you eat that might have table sugar in them?



SOMETHING TO TRY

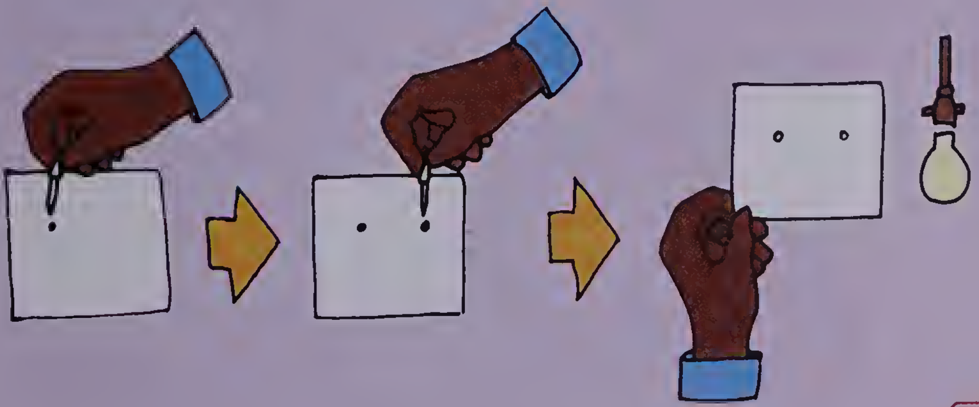
There is an easy test for simple sugar. But this test cannot be used for complex sugars. You can try this test yourself. First, get a piece of Tes-Tape® about 3 cm long. Then put it on an orange slice. Be sure the slice is wet. Wait one minute. Does the tape change color? Compare this color with the chart on the tape roll. Do you think the orange has a lot of simple sugar?

Get some samples of different kinds of foods. Put some juice from each food into a paper cup. Or, put a piece of the food into a paper cup filled with water. Label each cup.

Using a different piece of tape, test each food for simple sugars. Compare the colors with those on the chart. Which foods are high in simple sugars?

Fats. Foods such as meats, oils, and peanuts have fats. Fats also are energy foods when used by your body. Your body also can make fats. This happens when you eat more starches and sugars than you need at a certain time. Then your body stores this as fat. When you do extra work or exercise, your body might need extra energy.

Some fat in your body is important. It can give you quick energy when your body needs it. It also protects your body against heat loss. But if your body stores too much fat, then you might have a problem. Some parts of your body, such as your heart, must do extra work. The extra work could weaken and harm these body parts.



SOMETHING TO DO

When fat touches paper, it usually leaves a spot. If the paper is held up to a light, the spot lets a lot of light through. You can see how this works by making a simple test for fat.

First put a drop of water on a piece of paper. Then put a drop of cooking oil next to the water. Wait a few seconds. Hold the paper up to the light. Which spot lets more light through?

Make a list of foods that you think have fats. Get some samples of these foods. Test each food by rubbing it against the paper. Which foods make fat spots on the paper? Which do not?

	Makes grease spot	Doesn't make grease spot
Nuts	✓	
Rice		✓
Butter		
Cheese		
Orange		
Potato		

Proteins. *Proteins* are found in meat, fish, peanuts, and beans. Egg white is almost all protein and water. Cheese has a lot of protein. Milk has protein too.

Proteins build your body. They make it possible for your bones and muscles to grow. They keep your body strong. When proteins are used by your body, they also give you energy.

Many of the plants that animals eat have proteins. One way you can get these proteins is to eat the plants that make them. Another way is to eat animals that have eaten the plants.

Minerals. Most foods have some *minerals*. Certain kinds of minerals are used, along with proteins, to build bones. Others are used to build muscles and nerves. Still others are used for teeth and for blood. Minerals are used in all parts of your body.

One of the most important minerals is calcium. It is found in milk and many fresh vegetables. Calcium is used by your body to make healthy bones and teeth.

Other important minerals are phosphorus and iron. Iron is needed for healthy, red blood cells. Foods such as eggs, fresh vegetables, meat, fish, and milk are rich in minerals.

SOME PROTEIN FOODS

SOME MINERAL AND VITAMIN FOODS

Vitamins. *Vitamins* also keep you healthy. Your body uses them in small amounts. If your body does not get the right vitamins, you can become very sick.

Vitamins help all parts of your body to work properly. Some help your bones and teeth grow. Some help keep your skin healthy and your blood vessels strong. You must have certain vitamins to have good eyesight.

Your body can get all the vitamins it needs if you eat the right foods. Green, yellow, and red vegetables are rich in vitamins. Fruits, meats, and some breads and cereals also are rich in vitamins.

Your own body can make a certain vitamin if it gets enough sunlight. But too much sunlight can be harmful. Be careful not to burn your skin.

"Junk" foods. Some foods that you can buy have few or no proteins, vitamins, and minerals. Often these foods have lots of carbohydrates, such as table sugar. Most of these foods have been *refined*. That is, many things needed for good nutrition have been taken out.

Eating a lot of these foods can fill you up. But they will not help your body to grow and to stay healthy.

Water is important too. Water is found in all living things and in nearly all foods. Your body is mostly water. Nearly all living things are mostly water.

Water is important because it *dissolves,* or breaks down, many food materials into tiny bits. When food is dissolved, it can move through your body. Then your body can use the food for energy and for building body parts.

Water in foods we eat. All meats have water. Some of this water drops or steams out when meat is cooked. Milk and fruit juices are mostly water. Even dry cereal has a little water. Breads and rolls have a lot of water. When they lose water, they become hard and dry.

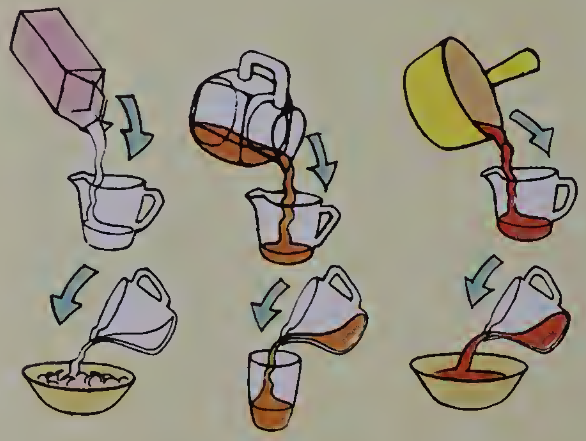
A PROBLEM

How much water is there in your diet? To find out, get a 250 mL measuring cup. Measure and record how much water you drink in one day.

In the morning, measure any liquid that you drink. Remember to measure any milk you put on your cereal. Do the same thing with juice, soup, and any other watery foods you eat. Keep this record for all your meals and snacks.

About how much water did you take into your body? Remember that foods such as meat, fruits, and vegetables have a lot of water. Do you take in a lot of water in one day? In one week? What happens to most of this water?

A person can live for days without most foods, but not without water.

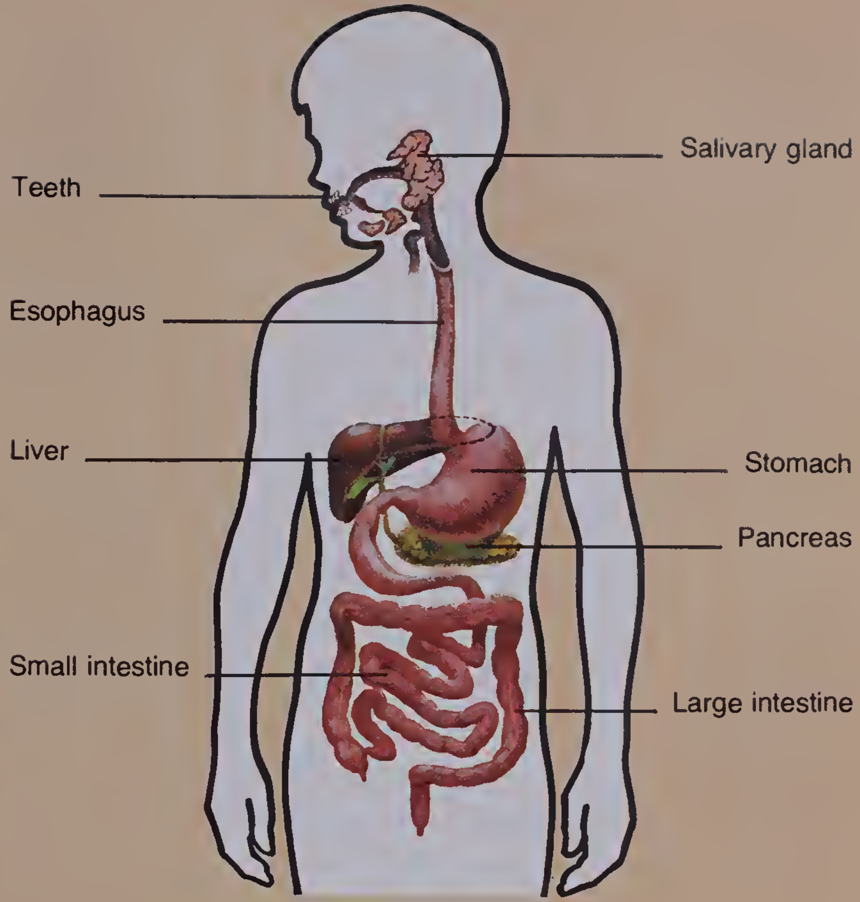


	Amount of Water
Breakfast	
Snack	
Lunch	
Snack	
Dinner	
Snack	

Your Digestive System LESSON 2

Living things are made up of tiny building blocks called *cells*. Food, water, and oxygen keeps these cells alive. But how do these materials get to the cells?

You have three systems that move food, water, and oxygen to your cells. They are your digestive, respiratory, and circulatory systems.



Food for your cells. The food you eat may not be ready to pass into your cells. Some must be broken down into smaller bits. For this to happen, the food often must be changed into another kind of matter. Your body makes these changes without your thinking about them. These changes may even take place while you sleep.

The picture above shows what food looks like when it is ready to pass into your body's cells. It is mostly water. But it has tiny bits of food in it. These bits are too small to see. Yet, they are small enough to pass into your cells.

Breaking down food. The process of breaking down food is called *digestion*. Digestion goes on in a tube that runs through your body. This tube has two openings. One opening is the mouth. There, food and water enter your body. The other opening is the *anus*. There, unused matter leaves your body.

These openings and the tube are part of your *digestive system*. In some animals, such as earthworms, the digestive system is almost straight. But if you look at the drawing above, you can see that yours has bulges and loops.

Food in your mouth. Your teeth grind up food. At the same time, *saliva* is added from your *salivary glands*. This liquid moistens the food. Also, saliva has *enzymes*. These chemicals help you digest certain foods.

What one class did. One class wanted to find out what change saliva caused in crackers. First they got a box of crackers. They read the label to make sure the crackers did not have sugar. Then they put a drop of iodine on one of the crackers. The cracker turned a blue-black color. This color change showed that the cracker had starch.

Next the students put a small amount of saliva in each of two test tubes. In a third test tube they put the same amount of water. They put bits of cracker into one of the test tubes with saliva. They also put bits of cracker into the tube that had water. Then the students stirred each of these mixtures with a different drinking straw.

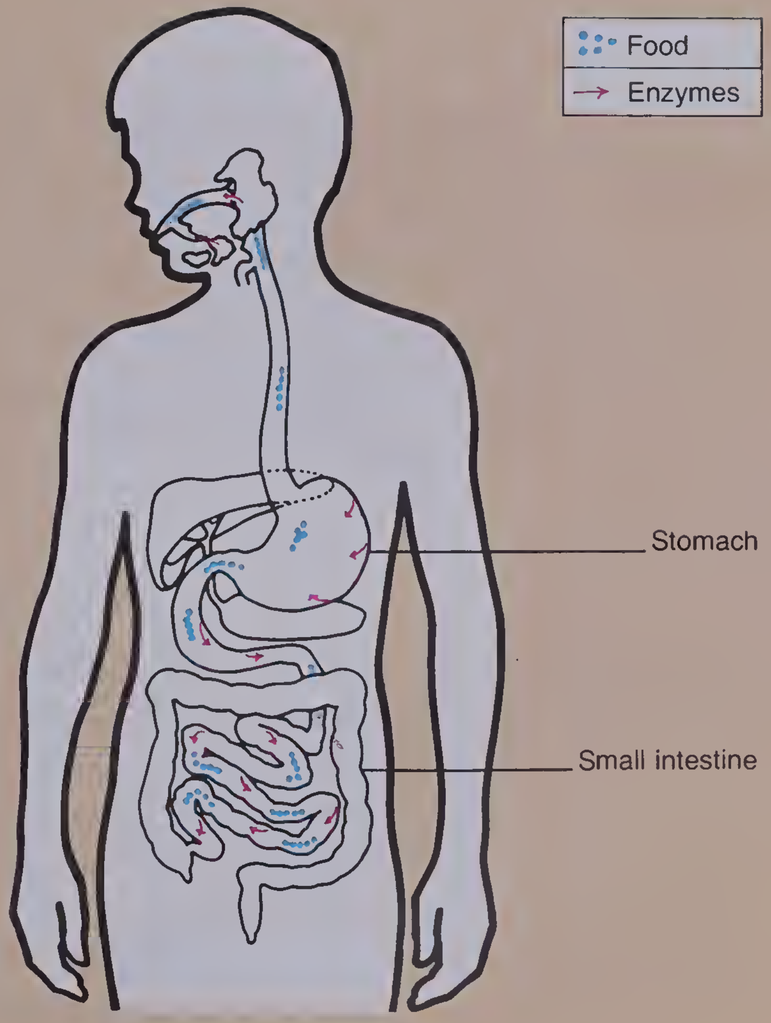
At the end of 10 minutes they tested each tube with a different piece of Tes-Tape®. The water and cracker did not turn the Tes-Tape® dark green. There was little sugar in the tube. The saliva did not turn the tape dark green. But the saliva and cracker did. Some of the starch in the cracker mixed with saliva. Then the starch was changed to sugar.

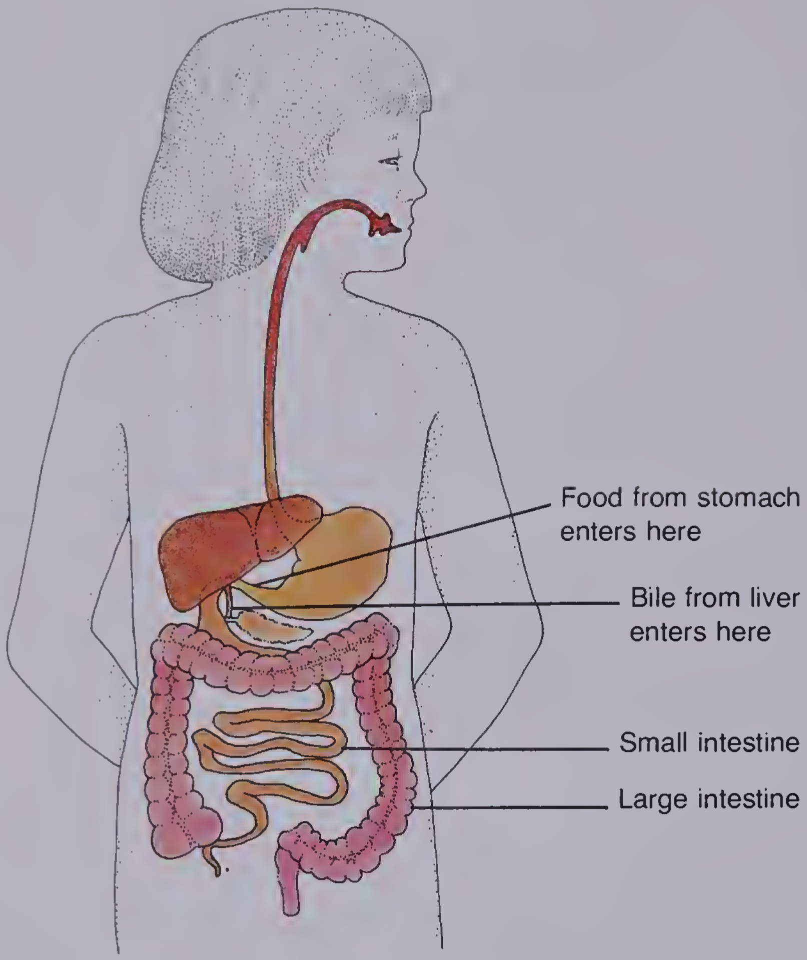
The importance of enzymes. As you chew food, enzymes in your saliva begin to work. One kind helps to change starch into sugar. But your body makes many different kinds of enzymes. Each kind causes some change in the food. If these changes did not happen, the food could not get into your cells. Then your body could not use the food.

Your stomach. After leaving your mouth, the chewed food passes through your food tube, or *esophagus*. Then it enters your *stomach*.

Your stomach is a sort of bag. It has muscles that contract often. This motion helps mix the food with juices made in the stomach. It is there that the breakdown of proteins begins.

Your small intestine. From your stomach, food passes into your *small intestine*. There it mixes with more enzymes. Some continue the breakdown of starch that began in your mouth. Others break down fats. Still others continue the breakdown of proteins that began in your stomach. In time the food is broken into smaller and smaller bits. Bits your body can use.





Bile from your liver. Your liver makes a juice called *bile*. This juice flows into your small intestine. Bile acts on the oil and fat in the food you eat. It acts like a detergent. It helps to split big drops of oil and fat into small ones. When fats are broken up, it is easier for enzymes to mix with them. Digestive enzymes cannot change fat particles unless they are able to mix with them.

SOMETHING TO TRY

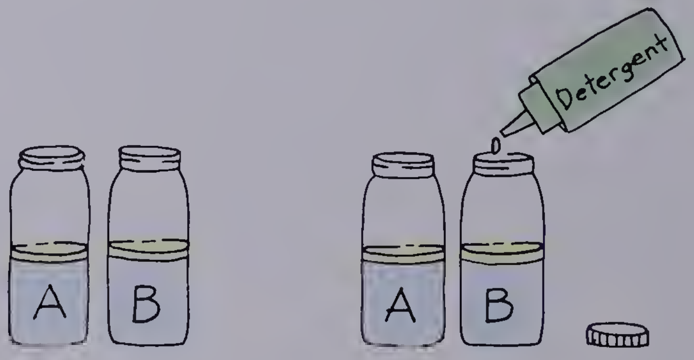
How are oils and fats broken down? Get two jars with lids. Label one jar "A" and the other "B." Half fill the jars with water. Add a few drops of food coloring to each jar. Then add 15 mL of cooking oil to each jar. Tighten both lids.

The food coloring does not mix with the oil. So the oil layer is easy to see. Now slowly tip each jar. What happens to the layer of oil? Why do you think this happens?

Now take the lid off jar B. Put a few drops of detergent in the jar. Put on the cap. Slowly tip both jars again. Compare the jars. What happens to the oil layer in each jar?

Were the drops of detergent strong enough to break up the oil layer into smaller drops?

Would one drop of detergent cause any change? How could you find out?

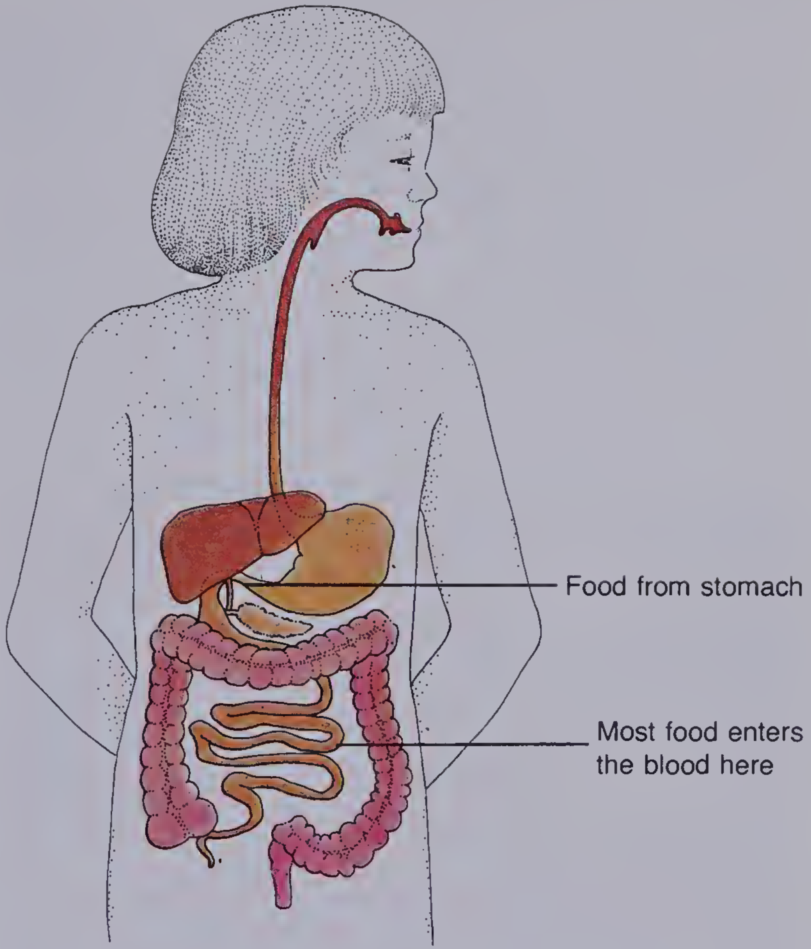


1. Tip and compare.

2. Add detergent.

3. Tip and compare. What happens?

Can all food be digested? Most foods have some matter that cannot be broken down. The seeds of some fruits and the strings in celery cannot be broken down. What happens to this food matter? It passes through the digestive system. But it is not used as food by the body. It passes as waste into the *large intestine.* There it is stored until it leaves your body.



Food into your blood. The digestive system changes large pieces of food into very small bits. Most of the changes in food happen in the stomach and small intestine. The inside surface of the small intestine is a membrane. The bits of food spread through the membrane. Many small blood vessels pick up the digested food. The blood then carries this food to cells all over your body.

Food into your cells. As your blood moves the bits of food through your body, they keep spreading. They spread out from the blood just as they did from the small intestine. In this way, the bits of food pass through cell membranes into your cells. Once the food is inside your cells your body can finally use it.

You cannot live for more than a few minutes without air. This is because you need *oxygen.* Oxygen is one of the gases in air.

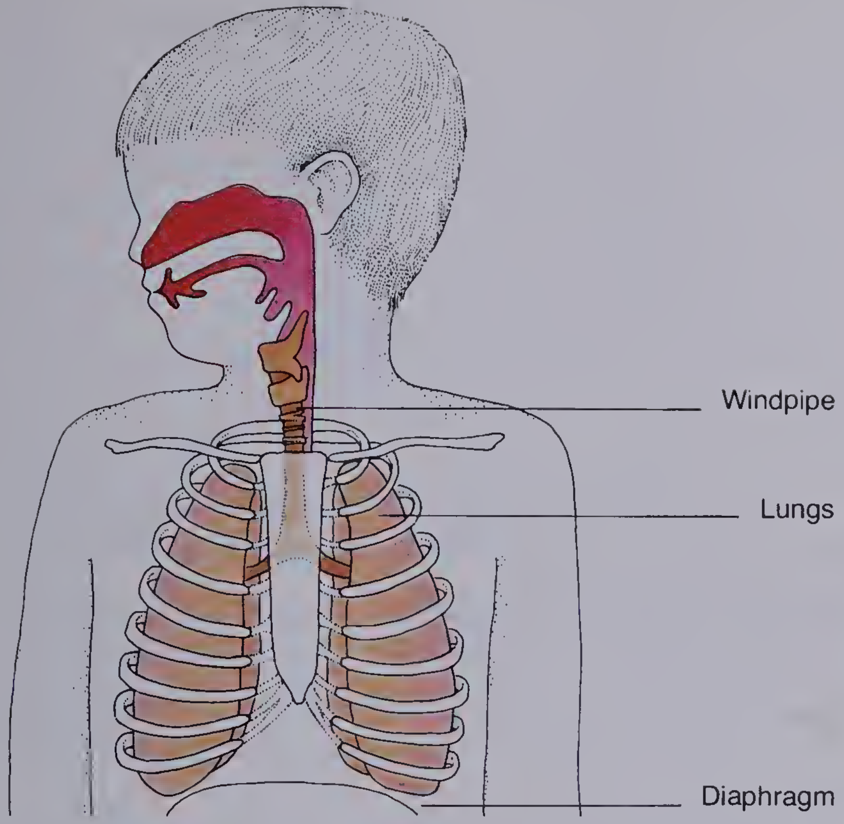
People who swim deep under the water must be able to breathe. Most often they carry an air supply with them.

Even fish in the deepest part of the ocean need oxygen. So do all the animals you might think of. But you may be surprised to find out that most plants also need oxygen. Living plants and animals on land and in water need it to live.

Taking in oxygen. Your body has many systems that work together. The system that helps you take in oxygen is your *respiratory system.*

Your respiratory system never rests throughout your lifetime. Night and day it moves oxygen to your body's cells. Your body needs food and water. But even more important is your need for oxygen. Oxygen combines with the food in your body. When this happens, energy is produced.

You take in oxygen from the air around you. But how does it get to your cells?



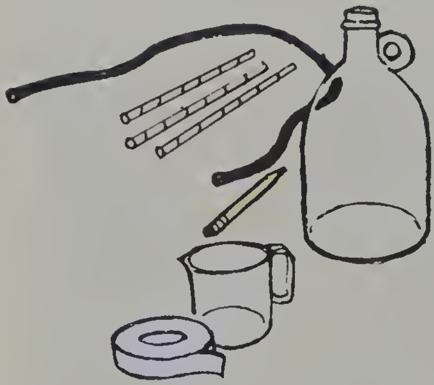
Air in your lungs. As you breathe, air moves into your nose or mouth. It passes down your throat and through your windpipe to your lungs.

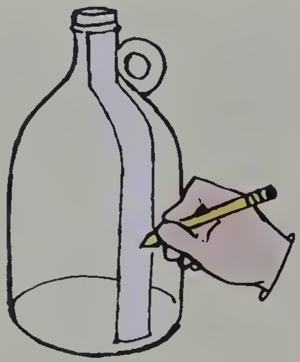
Lungs cannot take in and push out air by themselves. They do not have muscles. Instead, this is done by muscles along your rib cage. They make the size of your chest cavity larger or smaller. Also, under your chest cavity is a curved sheet of muscles called the *diaphragm*. When these muscles contract, the diaphragm flattens. This also makes the chest cavity larger.

A model respiratory system. One class made a model of the respiratory system like the one shown here. When someone pulled out on the rubber sheet (diaphragm), air rushed in. Then the balloons (lungs) filled. When someone pushed up on the diaphragm, the air rushed out. Then the lungs emptied. How is this model like a real respiratory system? How is it different?

SOMETHING TO DO

How much air can your lungs hold? To find out, first fasten tape to the side of a 5-L jug. Pour in 500 mL (one-half litre) of water. Mark the water level on the tape. Keep adding half litres. Each time, mark them off until the jug is full. Now you have a scale for measuring litres and half litres.





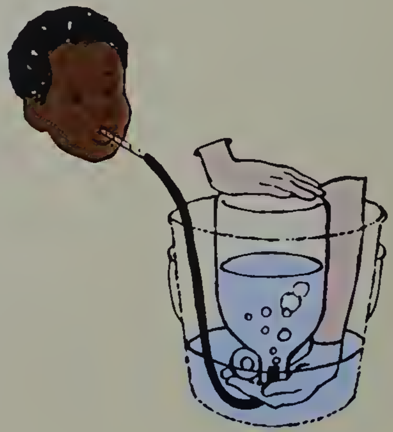
Next fill a pail about one quarter full with water. Have a classmate hold a hand tightly over the mouth of the filled jug. Now help your classmate turn the jug upside down in the pail. Make sure its mouth stays under water.

Stick one end of rubber tube into the mouth of the jug. Fit a plastic straw into the other end of the tube. Take a big breath. Steadily blow through the tube into the jug. What happens to the water in the jug as you blow?

When all of your "big breath" is in the jug, take out the tube. Make a mark on the tape to show where the air came. Put your initials at the mark.

Pour some of the water out of the pail. Now refill the jug with water. Turn it upside down as before. Place a new straw in the end of the tube. Now let someone else take a turn.

Find out how much air is in an ordinary breath. How does it compare with a "big breath"?



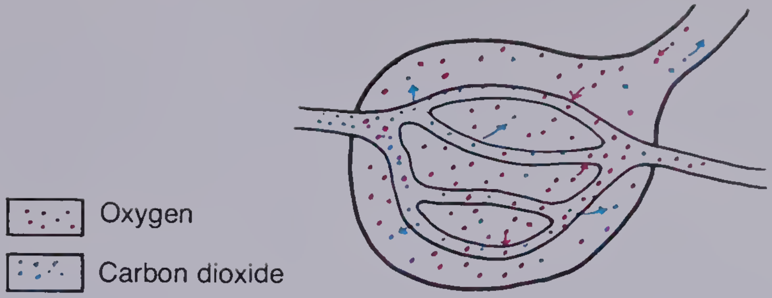
SOMETHING TO TRY

Is the air you breathe out the same as the air you breathe in? You can find out by testing some of each.

First pour some *limewater* into a test tube. Put a drinking straw into the tube. Now catch some room air in a plastic bag. Twist the bag shut. With a partner's help, push the free end of the straw into the bag. Slowly squeeze the air from the bag into the water. Make bubbles in the water. Does any change take place in the limewater as the air bubbles through it?

Now fill another test tube with limewater. Blow into another bag. Test this air the same way you tested the room air. What happens? Do you think the air from your lungs is the same as room air?

You have just made a test for *carbon dioxide* gas. Limewater turns cloudy when this gas is bubbled through it. Test air from some other places. Does this air make any changes in the limewater?

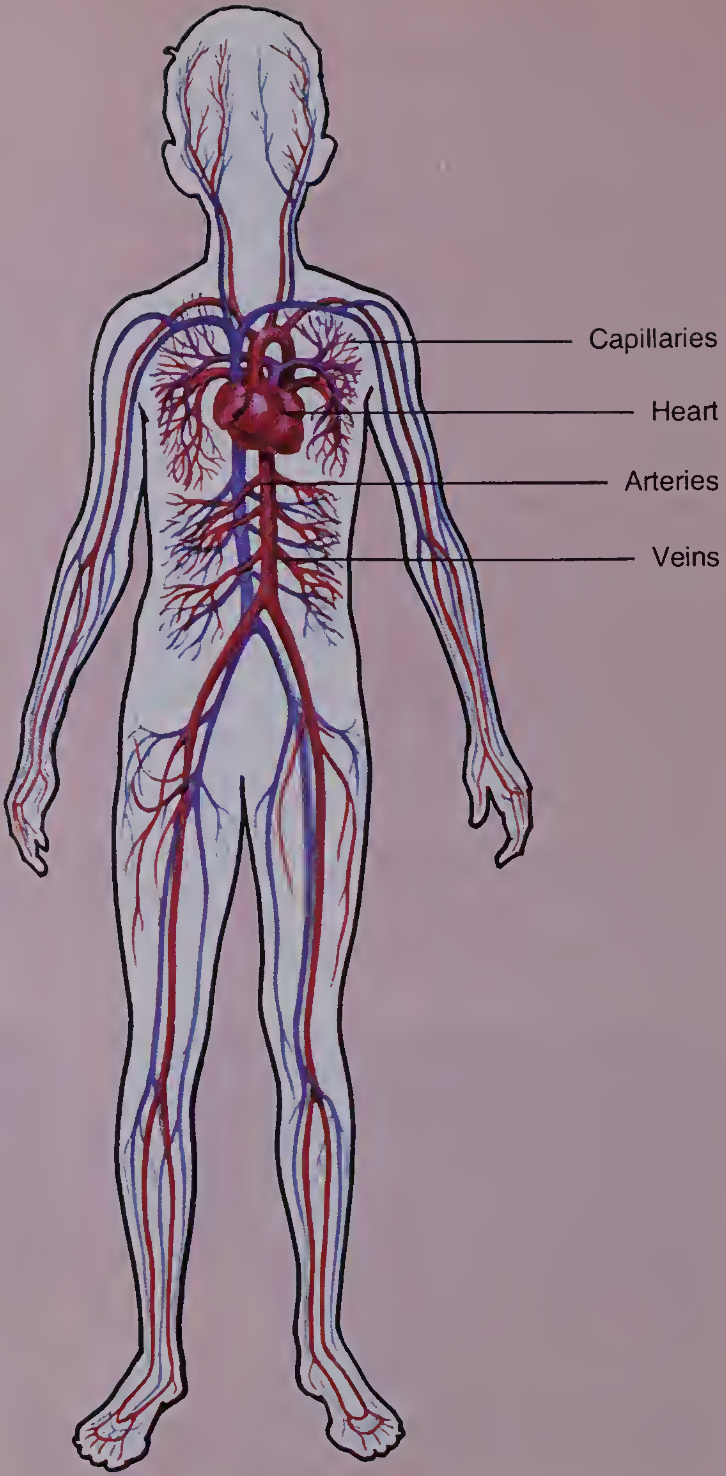


Oxygen and carbon dioxide. Where did the carbon dioxide come from? As your heart beats, part of your blood goes to your lungs. Your lungs have a great number of tiny air spaces. Around these are many tiny tubes that carry blood.

This blood has much carbon dioxide. The carbon dioxide comes from your body's cells, where food combines with oxygen. The carbon dioxide in your blood moves into the air spaces. These air spaces usually have lots of oxygen. So the oxygen moves into the blood. The blood flowing through your lungs "trades" carbon dioxide for oxygen.

Your Circulatory System LESSON 4

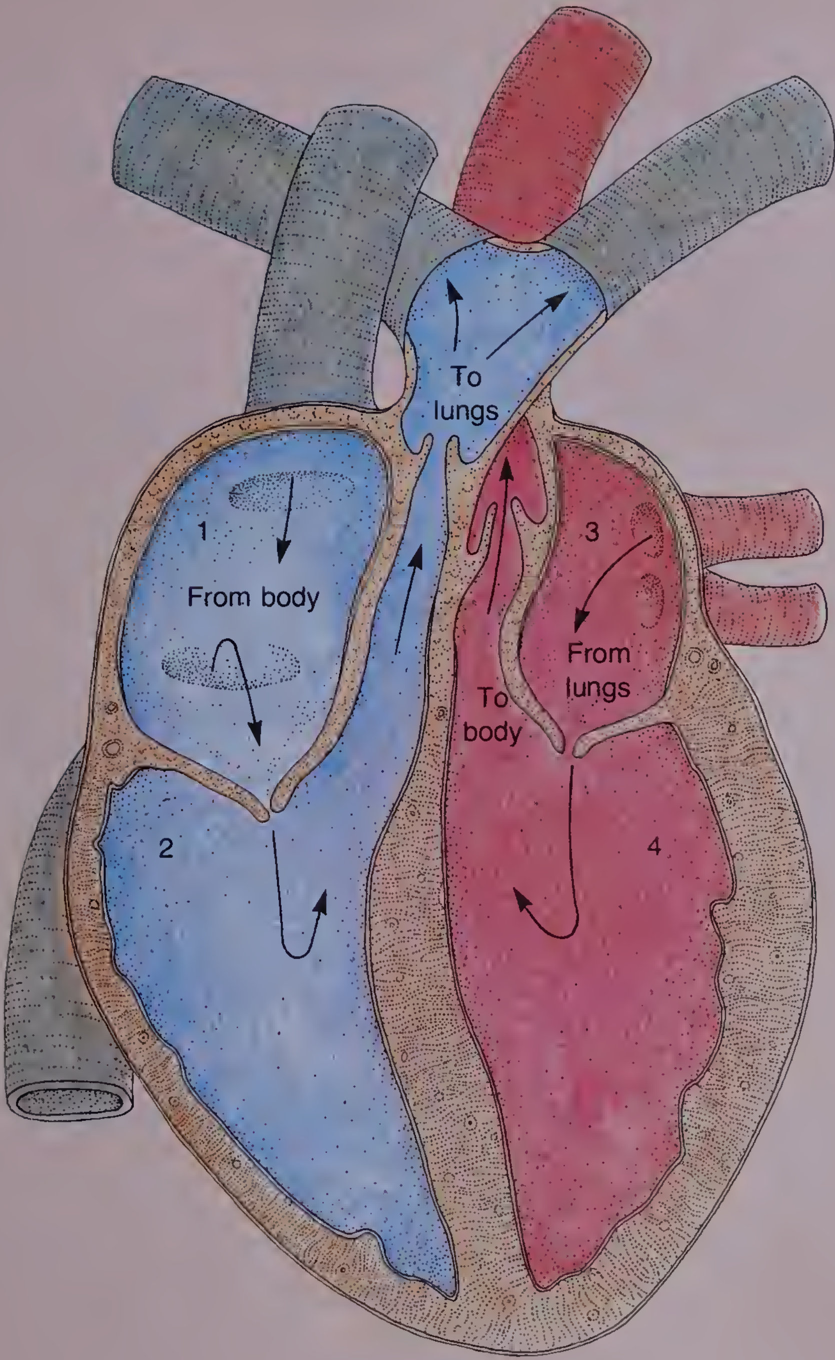
Can you guess how much blood you have inside your body? A litre? A half litre? Actually, you have more than 2 L. When you are an adult, you will have about 5 L of blood. This small amount is all you need because your blood *circulates*. It keeps going around and around your body. That is why the blood system in your body is called a *circulatory system*.



Substances in your blood. Blood carries food and oxygen to cells in all parts of your body. It also carries wastes away from your cells. This keeps the parts of your body working.

Your blood is mostly water. But it also is made up of millions of tiny red blood cells. These cells carry oxygen from your lungs. They also carry carbon dioxide back to your lungs.

There also are many bits of digested food in your blood. These bits mostly enter the blood from your small intestine.

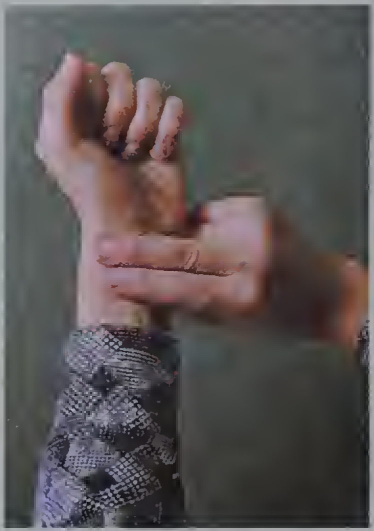


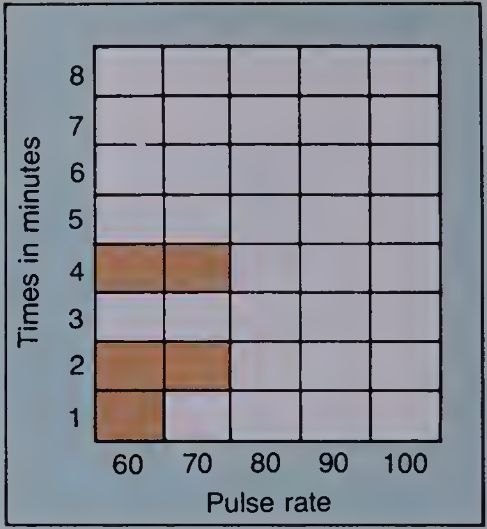
Your heart. Your heart is the center of your circulatory system. It is a pump that keeps working all your life. It is made of muscles that contract more than once each second. Each time it beats, it moves blood through your body.

Your heart has four sections, or *chambers*. Blood from your body enters the first chamber. Then it passes into the second chamber, where it is pumped to your lungs. What happens to it in the lungs?

Blood from the lungs enters the third chamber. Then it goes to the fourth and strongest chamber. From there, it is pumped all around your body. Flaps in the heart, called *valves,* open and close to keep the blood moving in one direction.

Your heart rests for only part of a second each time it beats. It does this from before you are born until you die. Minute after minute, hour after hour, year after year, your heart keeps beating. Can you see why your heart is called "the most important pump in the world"?





Arteries and capillaries. Your circulatory system also has many tubes of different sizes. With each heartbeat, blood moves through major tubes called *arteries*. These tubes carry blood away from your heart. They lead to your head, arms, legs, and other parts of your body.

As they carry blood away from the heart, arteries branch into smaller tubes. These are called *capillaries*. The smallest of these are smaller than hairs.

A major artery runs down each arm to your hand. In your wrist it is big. If you put your fingers on it, you can feel the blood pushing through it. Each "push" is caused by your heart beating. This is called your *pulse*.

SOMETHING TO TRY

Sit quietly. Put two fingers on your wrist as shown in the picture. Find your pulse. Have a partner time you. Take your pulse for one minute. This is your normal pulse rate. Record it.

Now exercise rapidly for one minute. Then find and record your pulse rate again.

Wait two minutes and take it again.

Keep taking and recording it every two minutes until your pulse rate is normal. How long does this take?

Make a graph of your records. Does your pulse rate seem to go down as quickly as it went up?

Now let your partner make a graph of his or her pulse rates. How do the graphs compare? After each person in the class has made a graph, compare them. Are there any big differences?

Food and oxygen in your cells. There are capillaries in most parts of your body. Around each one are living cells. Oxygen and digested food pass into these cells from the capillaries.

For a muscle cell to get energy, oxygen must combine with a bit of food. When this happens, heat is produced. That is why you feel warm when your muscles do work.

If you become too warm, your blood carries the extra heat to your skin. There some heat escapes into the air. Some also escapes when you perspire. This helps to cool you. Have you ever noticed this happen?

Getting rid of wastes. Waste products from your cells pass back into the capillaries as the blood keeps moving. Neighboring capillaries join each other, and form larger tubes called *veins.* Veins carry blood back to your heart.

From your heart, your blood goes to your lungs. There one waste product, carbon dioxide, leaves the blood. Your heart also pumps blood to other body parts. For example, blood goes to your kidneys. There other kinds of wastes are removed. They pass from your body as urine. More wastes leave through your skin when you perspire.

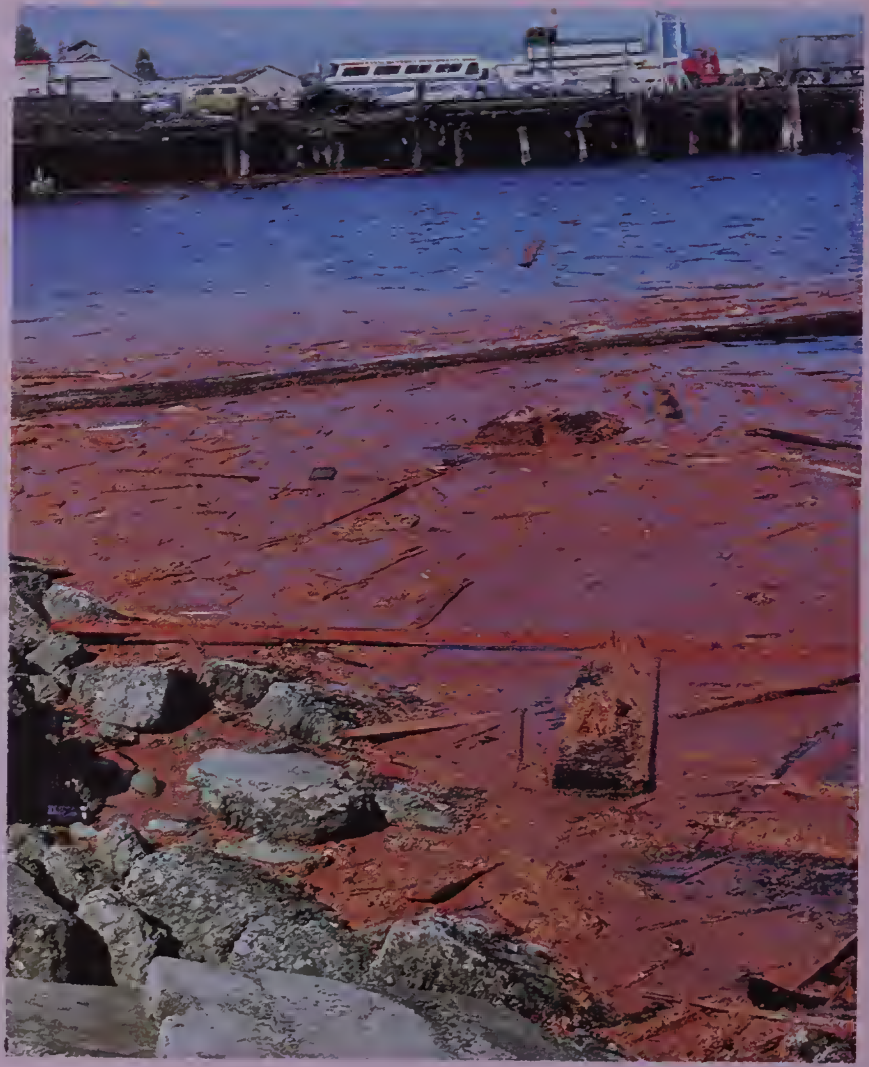
Things Your Body Does Not Need LESSON 5

You know that your body needs food, water, and air. But food, water, and air sometimes can have some things that your body does not need. It is possible that you even may not know these things are there.

Unwanted chemicals. Insects can cause a lot of damage to crops. So people often put insect poisons on their crops. These chemicals get into the insects and kill them. But other animals may eat these insects. In turn, these animals may be eaten by larger animals. The insect poisons get passed along.

Some of these chemicals can get washed into rivers and lakes. This can make the water unsafe to drink. The poisons also may get into tiny plants and animals that live in these waters. These living things may be eaten by larger animals. In time, the poisons may get into the food that people eat.

Factories often use chemicals. Sometimes they dump waste matter into rivers and lakes. The waste gets into tiny living things. Like insect poisons, these chemicals get passed along to other living things. They may end up in fish or other foods. When people eat these foods, they take these chemicals into their bodies. Too much of these chemicals may make people sick.



Unwanted things in the air. The oxygen you breathe comes from the air around you. As you take in oxygen, you may take in whatever else is in the air. Some of the unwanted things in the air may be harmful to you. Have you ever seen air that looks dirty? What did it look like?

Air often has chemicals from chimneys of factories, homes, power plants, and other buildings. It also has bits of dust and smoke from cars, trucks, buses, and airplanes.

Smoky, dirty air can be cleaned. It can be sent through a *filter*. But often it is not bits of dirt and smoke that are the most harmful. It is unwanted gases.

When gasoline burns in an engine, poisonous gases are given off. The more cars, buses, trucks, and planes there are, the more poisonous gases fill the air. Too much of these gases is harmful to plants and animals, as well as people. Poisonous gases also can come from chimneys of factories, power plants, and even homes.

SOMETHING TO TRY

Rub a thin coating of grease, or petroleum jelly, on each of two microscope slides. Lay each one, greasy side up, in an open box. Now, cover one box with a double layer of cheesecloth. Leave the other box uncovered.

Put both boxes outside in an open place. But do not let it rain on them. After two days, take the slides out of the boxes. Look at them under a magnifying glass. How do they compare?

Smoking harms your body. Suppose you asked some people whether they would take poison. Probably all of them would say "no." Yet some people do put harmful things into their bodies. Some people do not know how harmful these things are. Other people know. But they still put these things into their bodies.

Tobacco has substances that can affect your body. They make the heart work harder than it should. They can irritate the nose and throat. They can cause headaches and upset stomachs. They can even cause death.

When people smoke tobacco, they breathe in millions of tiny smoke particles. Many of these stay in the lungs. The lungs have air spaces. In time, the particles fill up these spaces. Then the lungs cannot work as well as they should. Some people get "short of breath." Their lungs cannot take in the amount of oxygen their bodies need. Sometimes people even develop lung cancer.

When people smoke tobacco, many smoke particles go into the air. Other people breathe in this air. Then what do you think happens to some of the smoke particles?

Drugs can harm your body. Doctors give drugs to help people who are sick. But some drugs can cause sickness, and even death. Any drug can be harmful if it is not used in the right way. "Drug abuse" is a term used when drugs are not used in the right way.

Many people do not think of alcohol as a drug. But it is. A person who drinks too much alcohol at one time may not think clearly. He or she may not speak or move normally. In time, alcohol can harm the brain, liver, and stomach.

Some drugs speed up the nervous system. They can make a person nervous, excited, or shaky. They can make a person not able to sleep. Some names for these drugs are "uppers," "speed," "pep pills," and "bennies."

Other drugs slow down the nervous system. Some of these drugs may even slow down a person's breathing. Taking too many of these drugs can harm the brain or other parts of the body. Some names for these drugs are "reds," "blues," "downers," and "barbs."

Ideas for REVIEW

- Your body needs food for energy, growth, and repair.
- Carbohydrates and fats have a lot of stored energy.
- Eating more carbohydrates and fats than you need, can make your body store fat.
- Too much stored body fat can be unhealthy.
- Proteins make it possible for your bones and muscles to grow and for your body to stay healthy.
- Minerals and vitamins help all parts of your body to work properly.
- The digestive system breaks down foods so that they can be used by body cells.
- The respiratory system takes in oxygen and gives off carbon dioxide and water.
- Oxygen combines with food in the body cells. This produces energy.
- The circulatory system takes food and oxygen to your cells. It carries away waste matter from the cells.
- Poisonous chemicals can get into water, air, and food.
- Many drugs, including alcohol and tobacco, are harmful to the body.

TEST Your Understanding

A. Use each of the following words in a sentence. Write your sentences on a piece of paper. *Do not write in this book.*

1. energy
2. nutrition
3. diet
4. circulate
5. digestion
6. pulse

B. Use the words from the following list to make each sentence correct. Not all the words are used. Write the answers on your paper.

circulatory
liver
fat
digestive
sugar
tobacco
heart
respiratory
oxygen
vitamins

7. Your heart is the main organ in your _____ system.

8. Your stomach is part of your _____ system.

9. Your _____ makes a juice called bile.

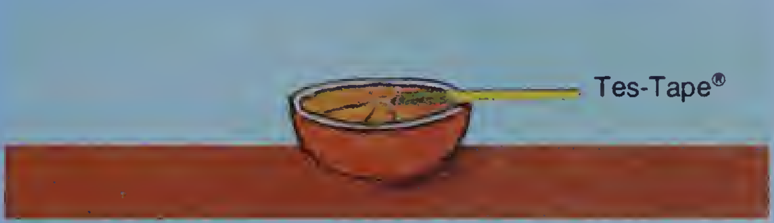
10. Enzymes in your saliva change the starch in a cracker to _____ .

11. Your lungs are the main organs in your _____ system.

12. _____ may harm your lungs and heart.

C. Each of these drawings shows a kind of test. What is each test for? Write the answers on your paper.

13.



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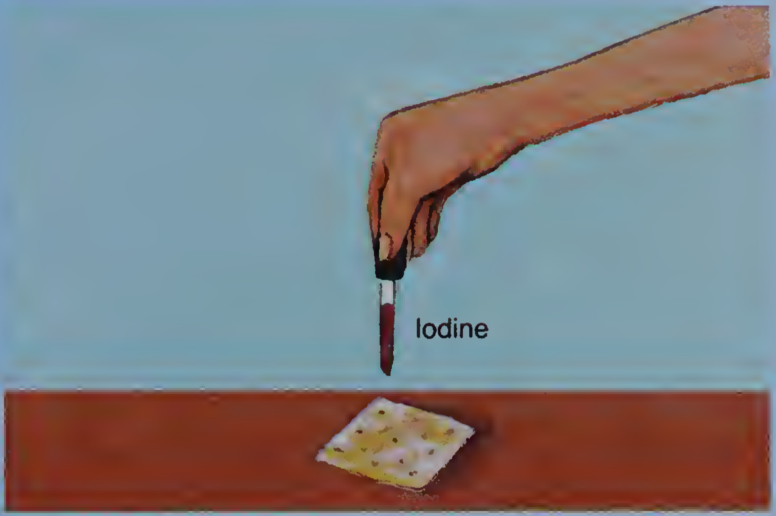

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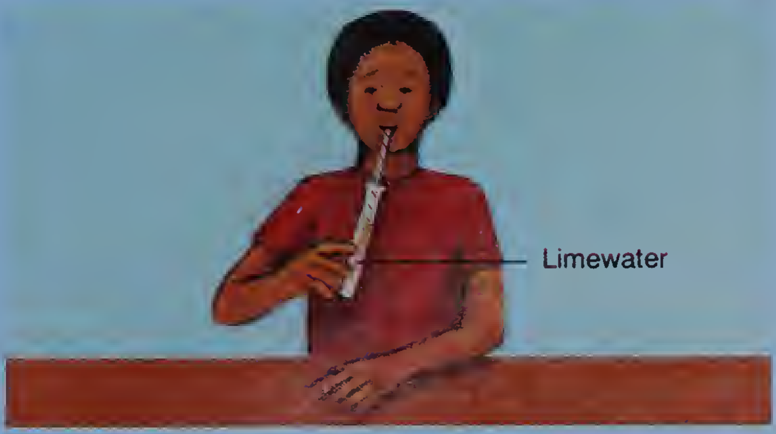
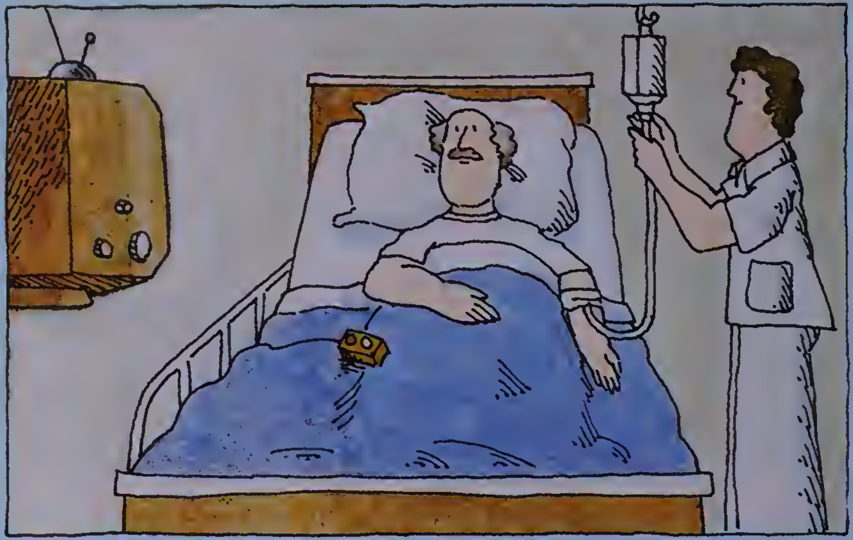


PROBLEMS

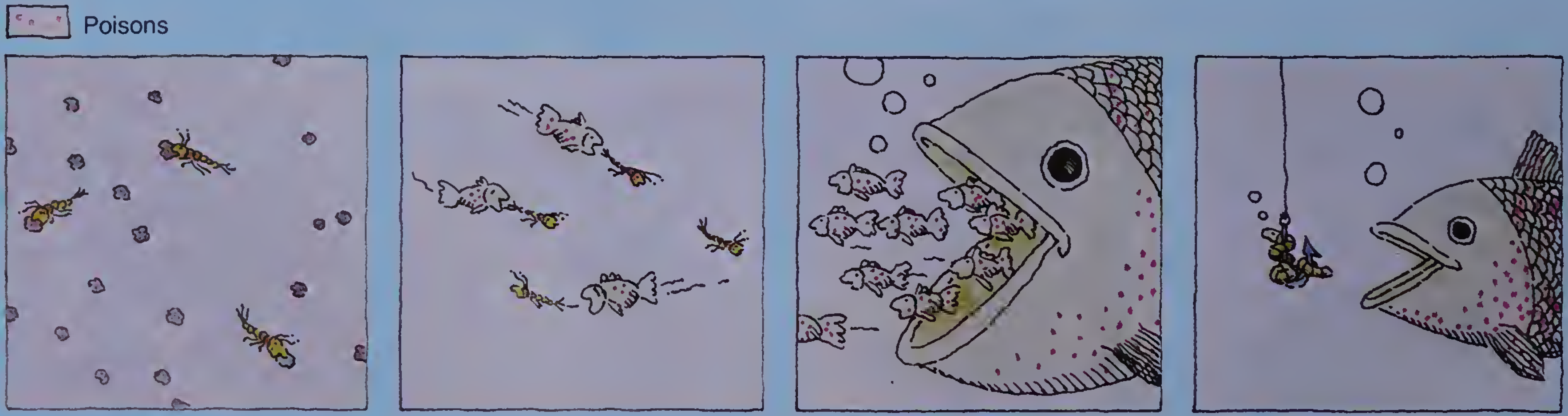
1. Sometimes when people are very sick, they cannot eat. They have to be fed through a tube that goes into a vein. Could they be given mashed potatoes through such a tube? Milk? Soup? A simple sugar mixed with water?

Suppose people had to be fed in this way for a long time. Do you suppose they need to be given vitamins and minerals, too? Why?

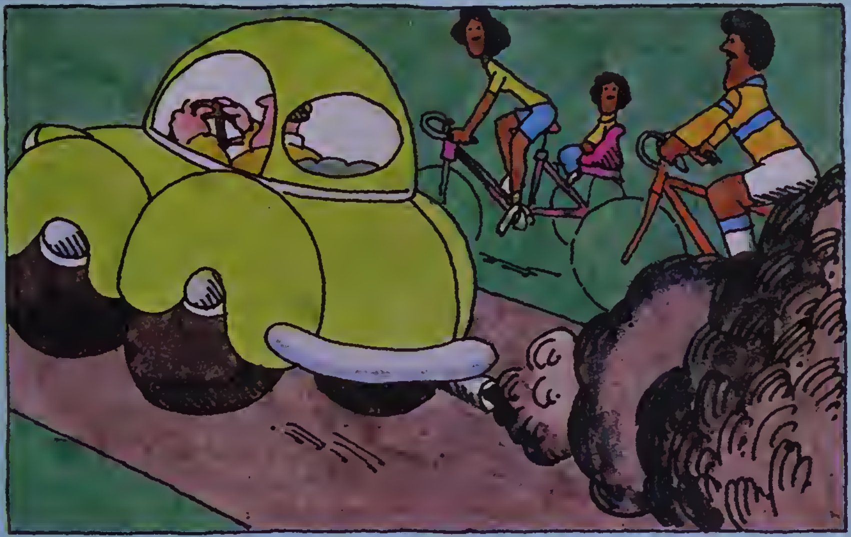


2. Suppose a tiny bit of a poisonous chemical got into many small water plants. Then a small water animal ate a lot of these plants. Would the poison get into the animal? Would the poison be a small amount? Or a large amount? Why?

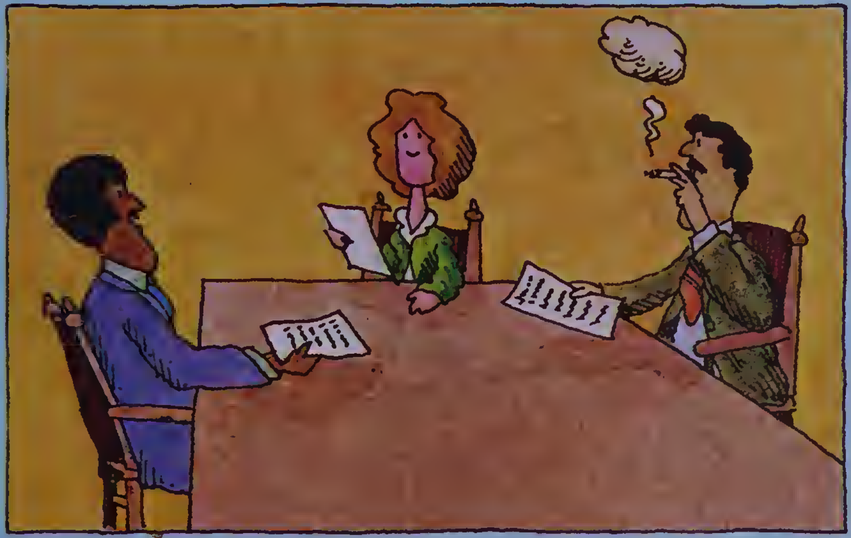
Now suppose many small animals ate a lot of these plants. Then these animals were eaten by a bigger animal. How much poison would get into the bigger animal? How might this poison get into a person? Would the poison be a small amount? Or a large amount? Why?



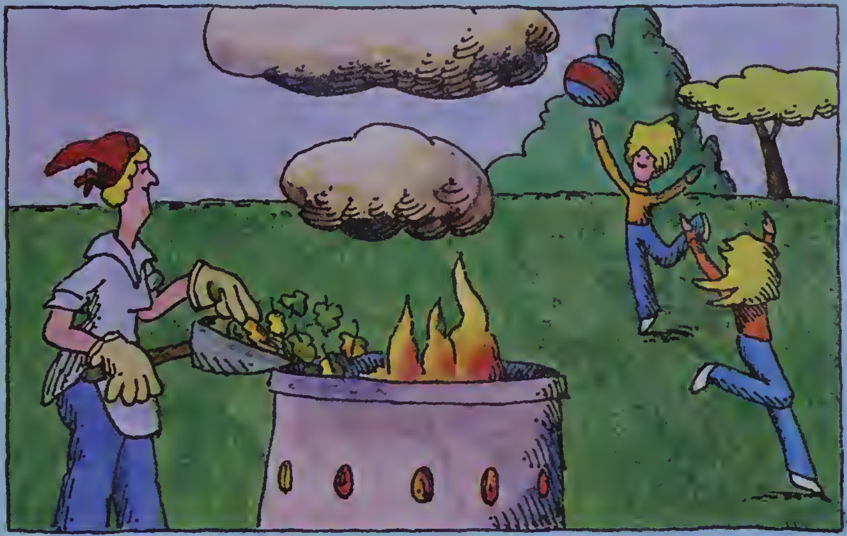
3. What is happening to the air? Who can be harmed? What could the driver do to stop it?



4. What is this man doing? Who can be harmed? What could he do differently?



5. What is this woman doing? Could she do something else? What?



FIND OUT on Your Own

Exploring jobs in food science. You know that good nutrition means eating the foods your body needs. There also is a science called nutrition. People who study this science often get jobs with the government, private food companies, and hospitals.

You might want to find out about some of these jobs. Ask your teacher or librarian to help you. Some topics to look for are:

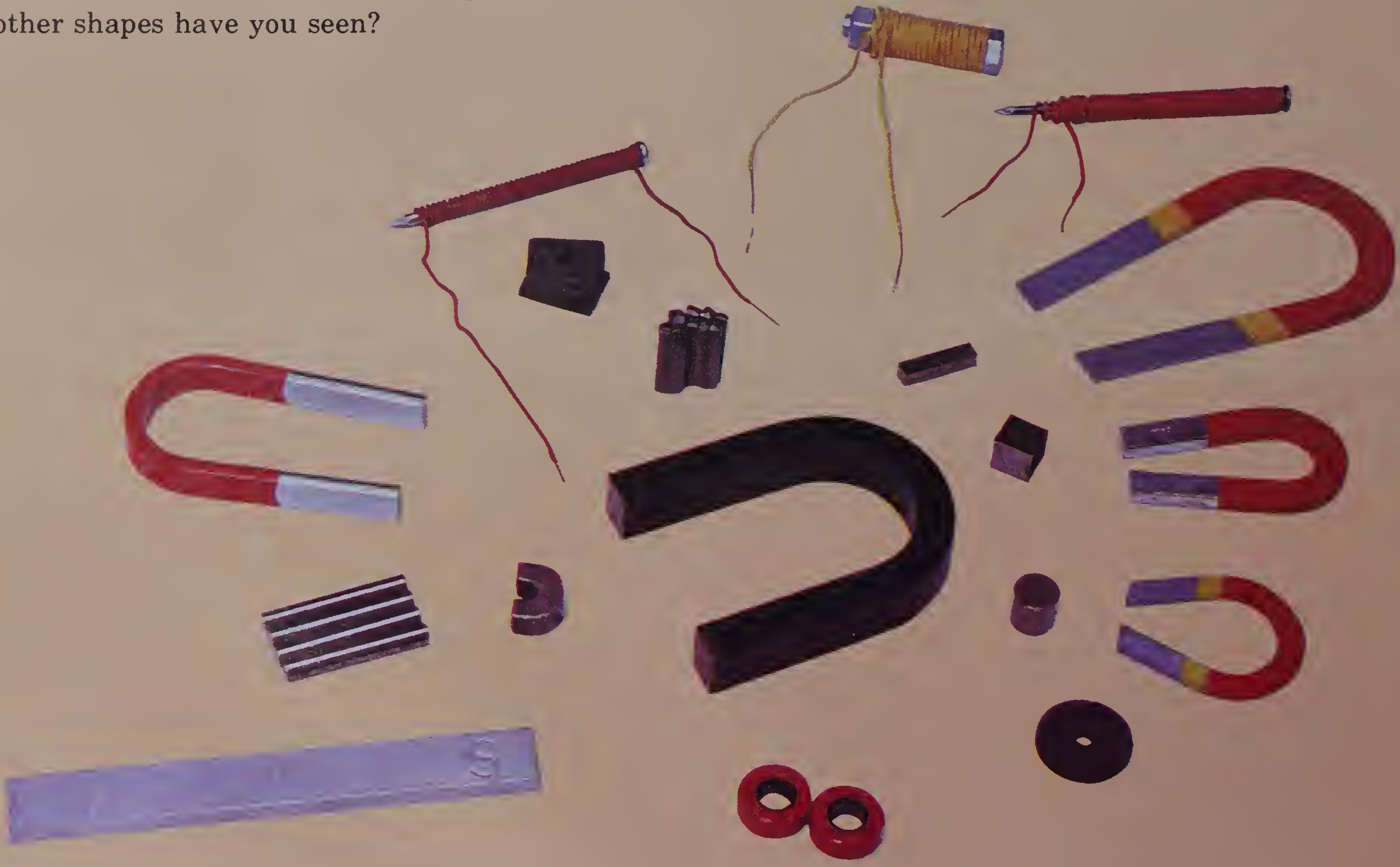
- food technologist
- nutritionist
- dietician
- home economist

5 Magnets and Their Uses

Most likely you have played with *magnets* at some time. Then you know they can pick up many things—but not all things.

What kinds of things can a magnet pick up?

What kinds of magnets have you used? How many can you recognize in this picture? What other shapes have you seen?



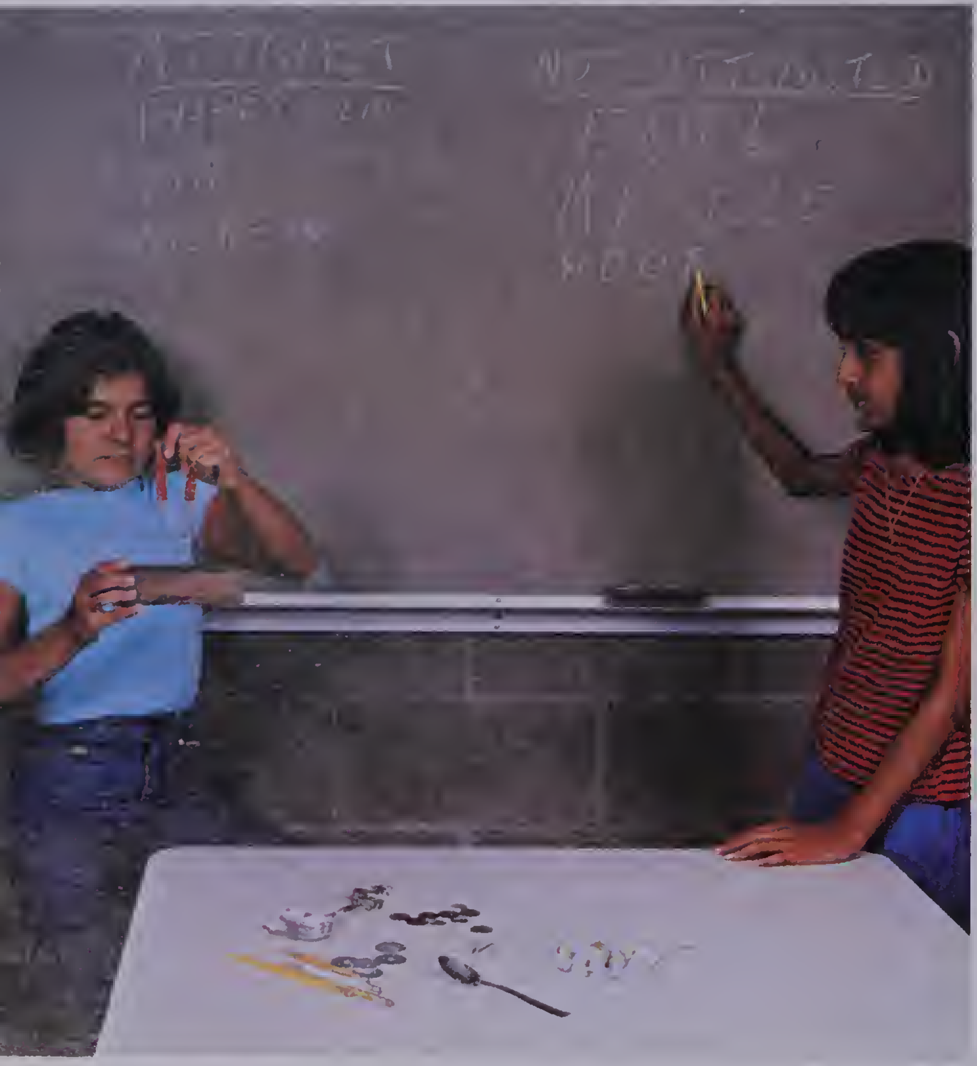
How do we use magnets? You may be surprised to find that many everyday things have magnets in them.

Look at the things shown on this page. Where is the magnet in each picture? What is each magnet used for?

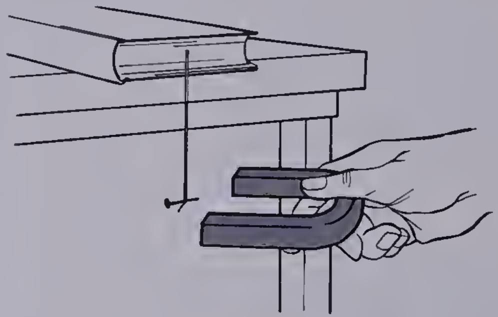
Are there any magnets around your home? If so, what are they used for? Can you think of any other places where magnets are used?

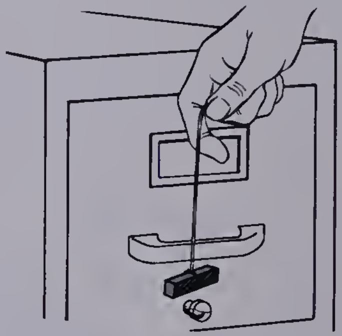
Attraction by Magnets LESSON 1

What are some things that magnets pull on, or *attract*? With your classmates, you can test all sorts of things. Keep a record of what you find. If a magnet attracts something, call the thing *magnetic*. If a magnet does not attract something, call the thing *nonmagnetic*.



Sometimes it is hard to tell whether a magnet attracts some things. If the object is small, tie a piece of thread to it. Then hang it up. When it stops swinging, slowly bring the magnet close to it. Try not to make a breeze. Otherwise the object may move because of the breeze.





If the object is large, hang a small magnet on a thread. Then slowly bring the magnet close to the object. Watch the magnet carefully. Is it attracted to the object?

Carefully study the things that are magnetic. Are they all alike? Are all of them solids? Or are some liquids or gases?

Are all the objects rather heavy for their size? Are they all metal? Do they all have the same color? Do they rust if kept wet awhile?

Some things that magnets attract have paint or other coatings on them. These coatings may hide the material that is underneath. To see what such a thing is really made of, you must scrape off the outside coating.

Ready-made magnets. You can buy magnets of many different sizes and shapes. You also can buy tools that are *magnetized*. How are magnetized tools helpful?

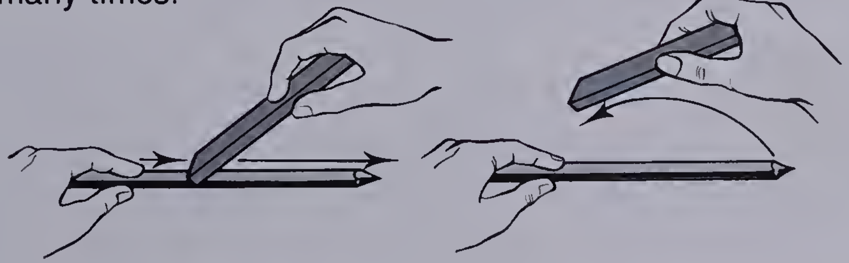
Some magnets that you can buy are stronger than others. They also keep their strength longer. This is because they are made of special kinds of steel or other materials.

Natural magnets. In some places magnets are found in the ground. They are natural magnets. A *lodestone* is a natural magnet. It is a piece of mineral called *magnetite*. Magnetite contains iron and is a type of iron ore.

If you can borrow a lodestone, test it with small nails or paper clips. Do they stick to it better at some places than at others?

SOMETHING TO MAKE

It is easy to make your own magnet from a steel object. Just stroke it with a magnet from end to end. Do this many times.



Use only one end of the magnet. Stroke the object with this end. Stroke it in one direction only. On each return trip, be sure to keep the magnet as far away from the object as possible.

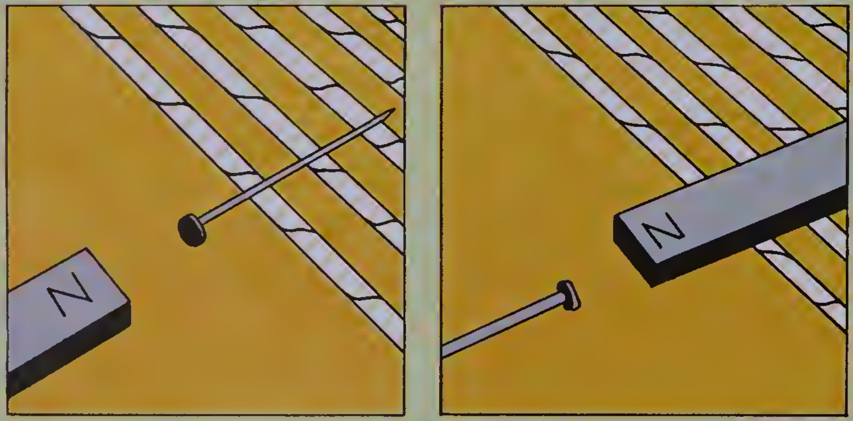
How many strokes must you give the object before it can pick up a paper clip? If you give it twice as many strokes, will it pick up two paper clips? Will it keep getting stronger if you keep on stroking it?

SOME THINGS TO INVESTIGATE

1. How can you tell solid brass from brass-covered steel?

With a magnet, test some solid brass objects such as paper fasteners and screws. What happens? Now test other metal things that look like brass. What happens? Test curtain rods, picture frames, and table or floor lamps. Which things are solid brass? Which things are really steel?

Think about what you have seen. Is all metal that looks like brass really brass?



2. If a magnet attracts a nail, does the nail also attract the magnet?

Lay a large nail across a few drinking straws on a smooth table top. Then bring one end of a magnet close to one end of the nail. What happens? Why does it happen?

Next, place the magnet on the straws. Bring one end of the nail close to one end of the magnet. Now what happens? Why does it happen?

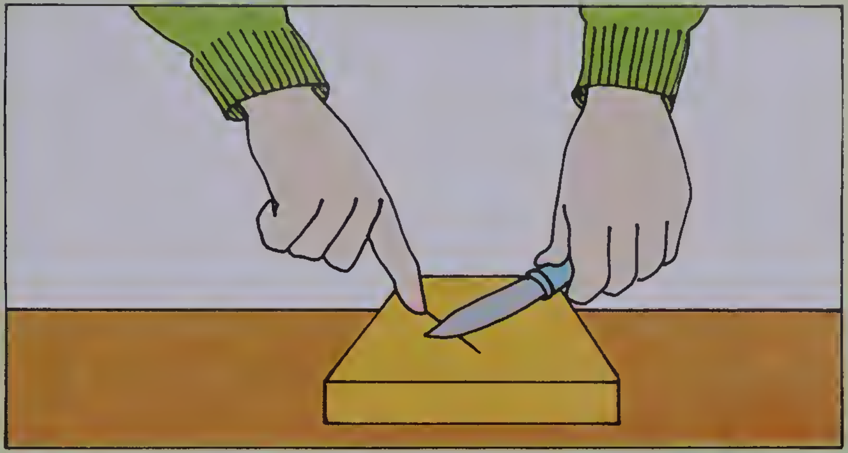
3. Are there any metals besides iron and steel that are magnetic?

Test a lot of straight pins with a magnet. Most likely you will find that the magnet strongly attracts some pins. These are made of steel. The magnet only weakly attracts other pins.

Now take a pin that the magnet attracts only weakly. Scrape off a little of the metal from the outside of this pin. Test the scrapings with the magnet. What happens?

Compare the color of the metal on the outside of the pin with that on the inside. Can you see any difference in color? Scrape off every bit of the outside metal. Then does the magnet attract the pin?

Pins like this are made of brass with a thin coating of *nickel.* Nickel is a silver-colored metal. It is magnetic, like iron and steel. But it does not rust as iron and steel do.



4. Are there magnetic grains in sand found near where you live?

Sprinkle a little dry sand on a sheet of paper. Have someone lift the paper by its edges and hold it level. Then move a magnet under it.

Does the magnet attract any of the sand grains? If so, what do you suppose these grains are? What do you predict will happen to them if you keep them in water overnight? Test your prediction.

5. Will a homemade magnet keep its strength a long time?

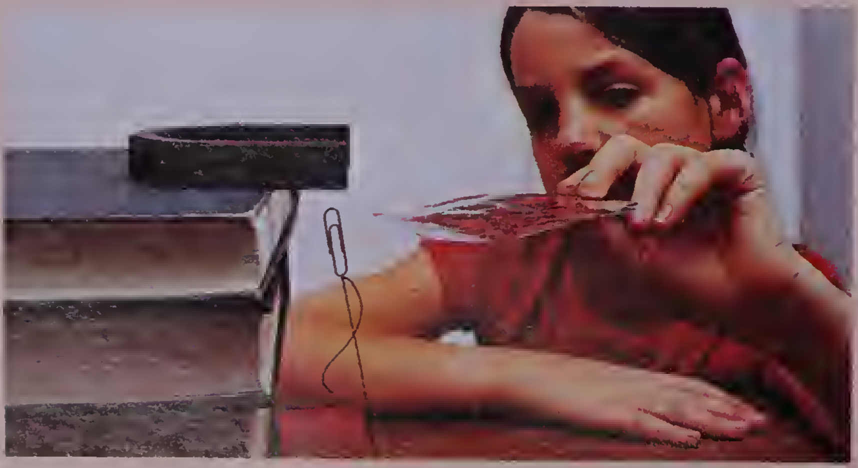
You may have wondered about this question. How could you find out the answer? How would you measure the strength of the magnet? How often would you do this? What records would you keep?

Weakening magnets. Why do magnets become weak? You can discover one reason.

Magnetize a nail file, hacksaw blade, or other steel object. Test its strength by counting how many small nails it can pick up. Count and record the number of nails.

Now bang this magnet very hard against a block of wood. Do this 10 times. Or drop it on a hard floor or sidewalk 10 times. Then test its strength. Has there been any change?

What will happen if you bang or drop the magnet 10 more times? Try it. What happened?



This shows how to take care of magnets. If you want them to stay strong, handle them gently. Never drop or bang them. You should handle magnets as you would fresh eggs.

Heating magnets also can weaken them. For example, the magnetized needle shown in the picture below could pick up a paper clip. Then it was heated until it was red hot. After it cooled, it was tested again. It could no longer pick up the paper clip.

Safety Note: *Never heat a magnet unless an adult is present.*

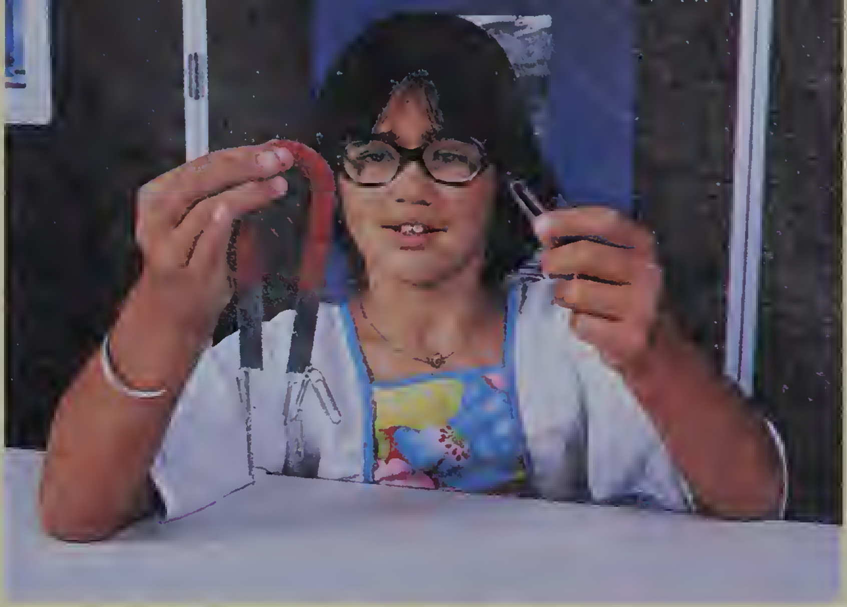
Magnetic shields. The girl at the left will slip the aluminum foil between the paper clip and the magnet. What will the paper clip do?

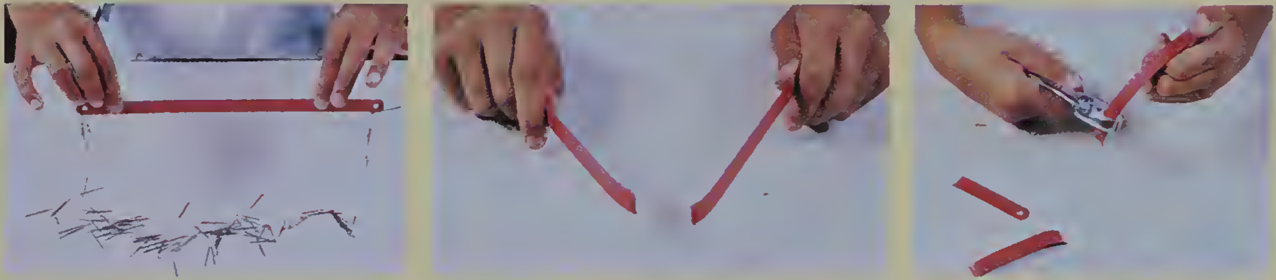
You can easily check your idea. You also can test other materials, such as paper, plastic, and steel. Just be careful not to touch the paper clip or the magnet.

Any material that blocks the pull of a magnet is a *magnetic shield*. Did you find any material that did this? What is this material?

Poles of magnets. Have you noticed that nails and paper clips stick best to certain places on a magnet? These places are called the *poles* of the magnet.

Where are the poles of the magnets you have been using? How many poles does each of these magnets have?





SOMETHING TO TRY

Can you make a magnet with just one pole?

To find out, first magnetize a hacksaw blade as strongly as you can. Then test the blade with small nails to find its poles.

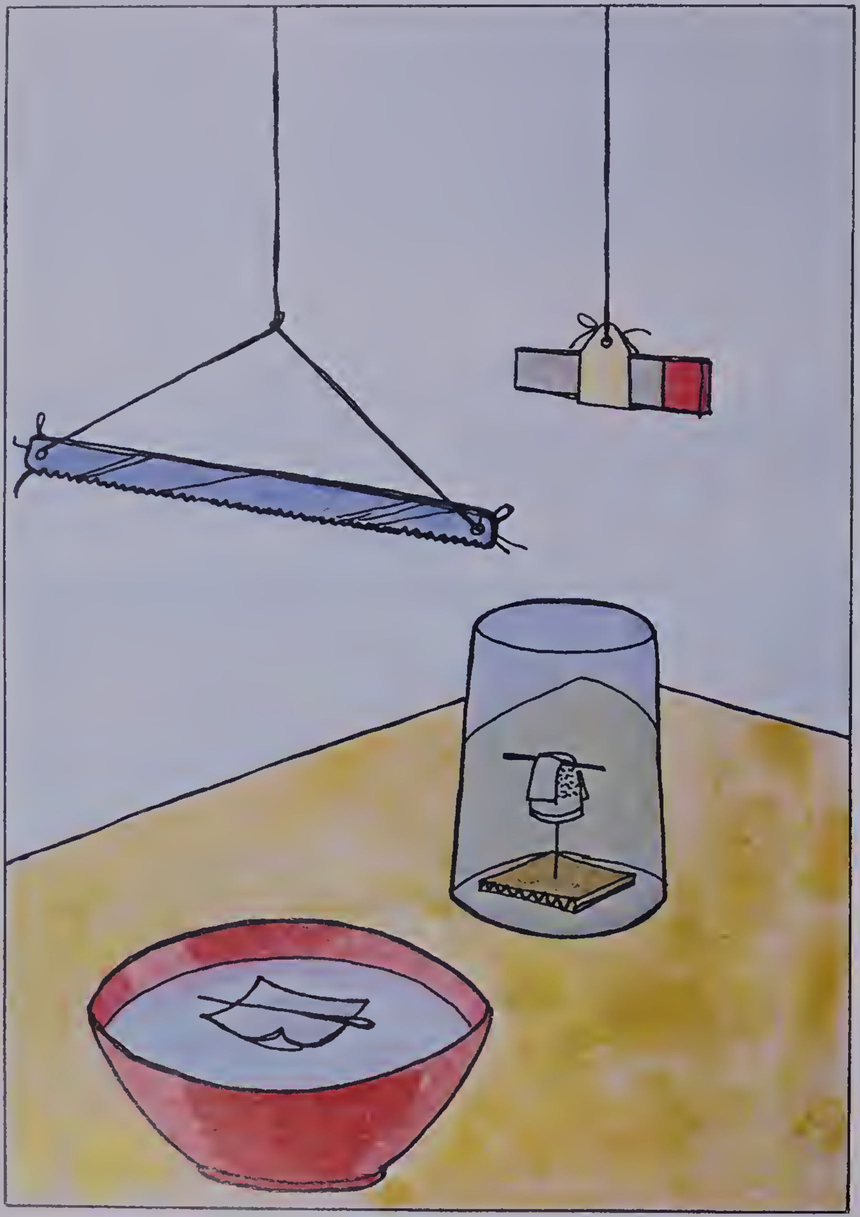
Suppose you broke the blade in half. How many poles do you predict you would find? Where would each of them be found?

Now crack the blade in half by bending it double. Then test both halves for poles. What do you find?

Now, break each half in two. Test each piece for poles. Then, with pliers, break off still smaller pieces. Test them, too.

Are you able to break off a piece that has only one pole? Can you make a one-pole magnet in this way?

You can set up a magnet so that it can turn around freely. The drawings show some ways of doing this. Can you think of others?



SOMETHING TO TRY

How do freely turning magnets act?

Set up a long, straight magnet so that it can turn freely. Make sure it is far away from other magnets. Also make sure it is far away from any iron or steel.

Wait until your magnet comes to rest. Then look at its position. Also look at the freely turning magnets that your classmates have set up. How do the positions of their magnets compare with yours? Your classmates can hold out their arms to show the position of their magnets. This will make it easy to check.

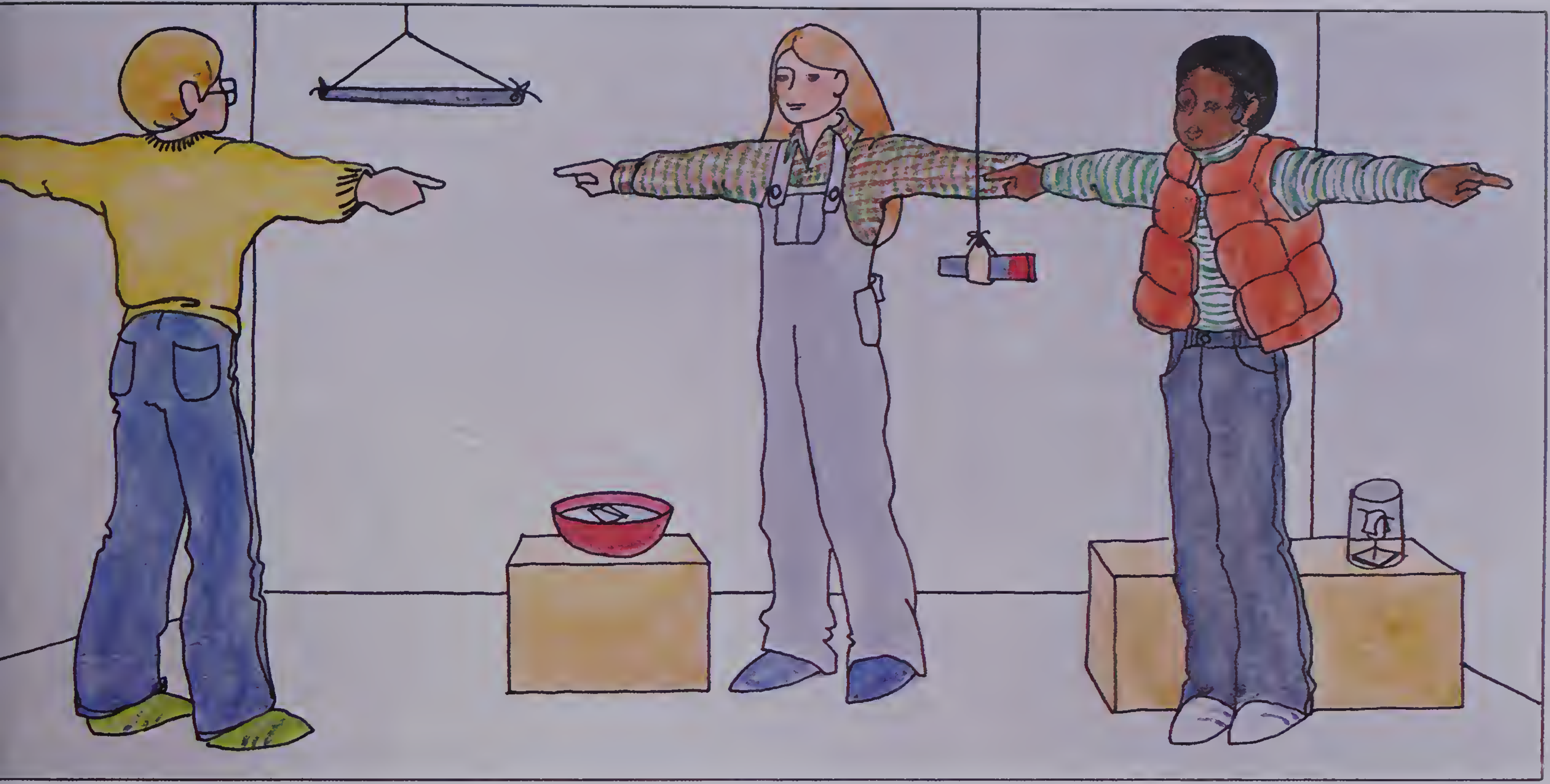
Mark one end of your magnet. You can mark it with chalk, a paper sticker, or a dot of nail polish. Now, spin your magnet around. Wait until it comes to rest. Does it go back to the same position?

Do this step several times. Does your magnet go back to the same position each time?

Does a freely turning magnet take this same position in another part of the building? Does it take the same position outdoors as it does indoors?

Outdoors, wind may turn the magnet. But you can stop this from happening. Put it inside a box or under a jar or tumbler. Just make sure that the magnet still can turn freely.

You may be able to take your freely turning magnet home. If you do, does it take the same position at home as it does at school? If your classmates took their freely turning magnets home too, what were their results?



Magnetic compasses. A freely turning magnet takes a certain position. And after someone spins it around, it goes back to this position. Usually one end points north. And the other end points south.

A freely turning magnet is a *magnetic compass*. It shows direction. Of course, one end of the magnet must be marked in some way. Usually, it is the end that points toward the north. This is the *north-seeking pole* of the magnet. The other end is the *south-seeking pole*.

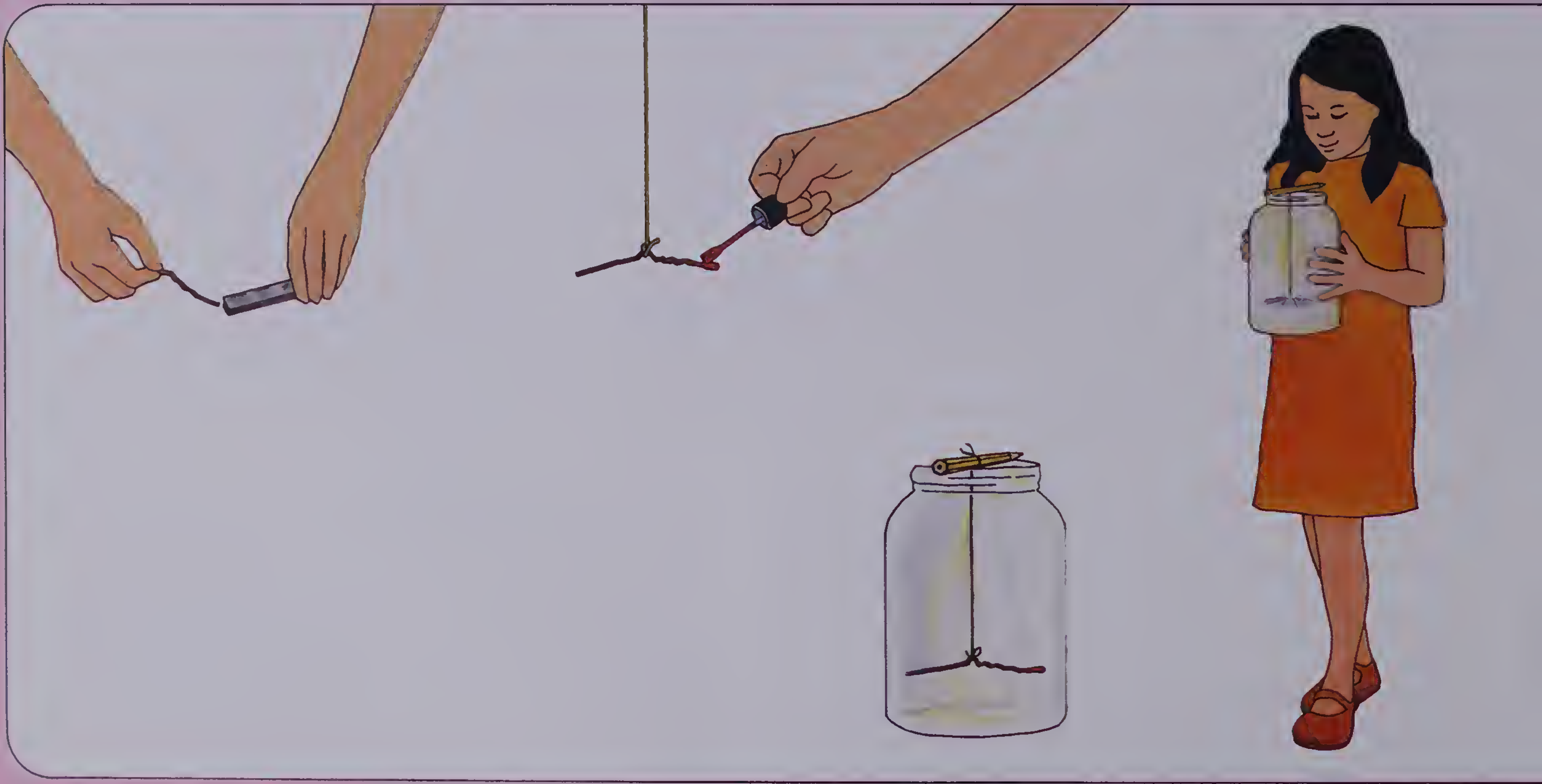
A magnetic compass that you buy usually has a long thin magnet inside it. This is called a needle. The needle turns freely inside a case. The case is made of a nonmagnetic material. Why do you think the case is made of this?

A homemade compass. This girl made her own compass. First she straightened out a bobby pin. She magnetized it strongly. Next she hung it on a thin thread. She put a little nail polish on its north-seeking pole. Then she hung it inside a large jar. It hung level and did not touch the glass.

The jar kept the wind from turning the bobby pin. But when the girl walked around with the compass, the bobby pin swung wildly. Would a compass like this be good for use in an airplane or on a boat? Why?

The girl then tried something else. She filled the jar with water. Once the water stopped moving, the bobby pin stayed quietly in one position. It stayed this way even when she turned the jar around.

The water stopped the bobby pin from swinging wildly. But, it did not stop the bobby pin from showing direction.



Liquid-filled compasses. Magnetic compasses often are used in automobiles, boats, and airplanes. Compasses like these usually have a *dial* instead of a needle. The dial turns freely. It has small magnets fastened to it. These magnets usually stay in one position. They keep the dial in one position.

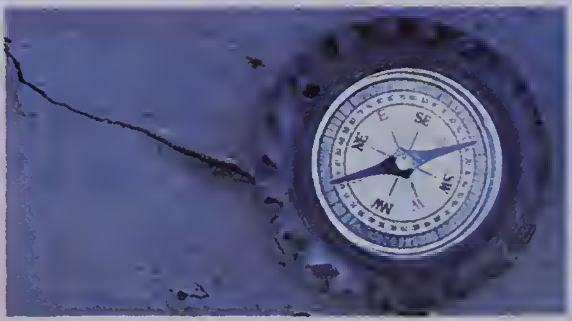
These compasses usually are filled with liquid. The liquid keeps the dial from turning wildly. But the liquid is not water. Why wouldn't it be good to use water?

Things that affect a compass. A compass may not show direction correctly when magnets and magnetic materials are nearby. Even steel beams and iron pipes in a building may affect it. For this reason, a compass usually works best outdoors. But even there, underground pipes may affect it.

In some places, there are large amounts of magnetic iron ore in the ground. This, too, may affect a compass. In fact, this is one way to locate magnetic iron ore.

Using a compass. To use a compass, first set it on something level. Be sure no iron or steel is near it. Wait until the needle comes to rest. Then its north-seeking end, usually colored blue, will point toward *magnetic north.*

Now turn the compass until the "N" is under the north-seeking end of the needle. Then the "S" will point out magnetic south. The "E" will point out magnetic east. And the "W" will point out magnetic west.



Magnetic directions and true directions. In most places, magnetic north is not the same direction as *true north.* In North America, they are the same only in the area colored 🟪 on the map. In the areas colored 🟥🟥🟥🟥🟥🟥 a compass needle points toward the right, or east, of true north. In the areas colored 🟦🟦🟦🟦🟦🟦 a compass needle points toward the left, or west, of true north.

In California is magnetic north toward the east or west of true north? In Ontario?

Where would a compass needle point more nearly to true north—in Manitoba or Alaska? In Maine or Pennsylvania?

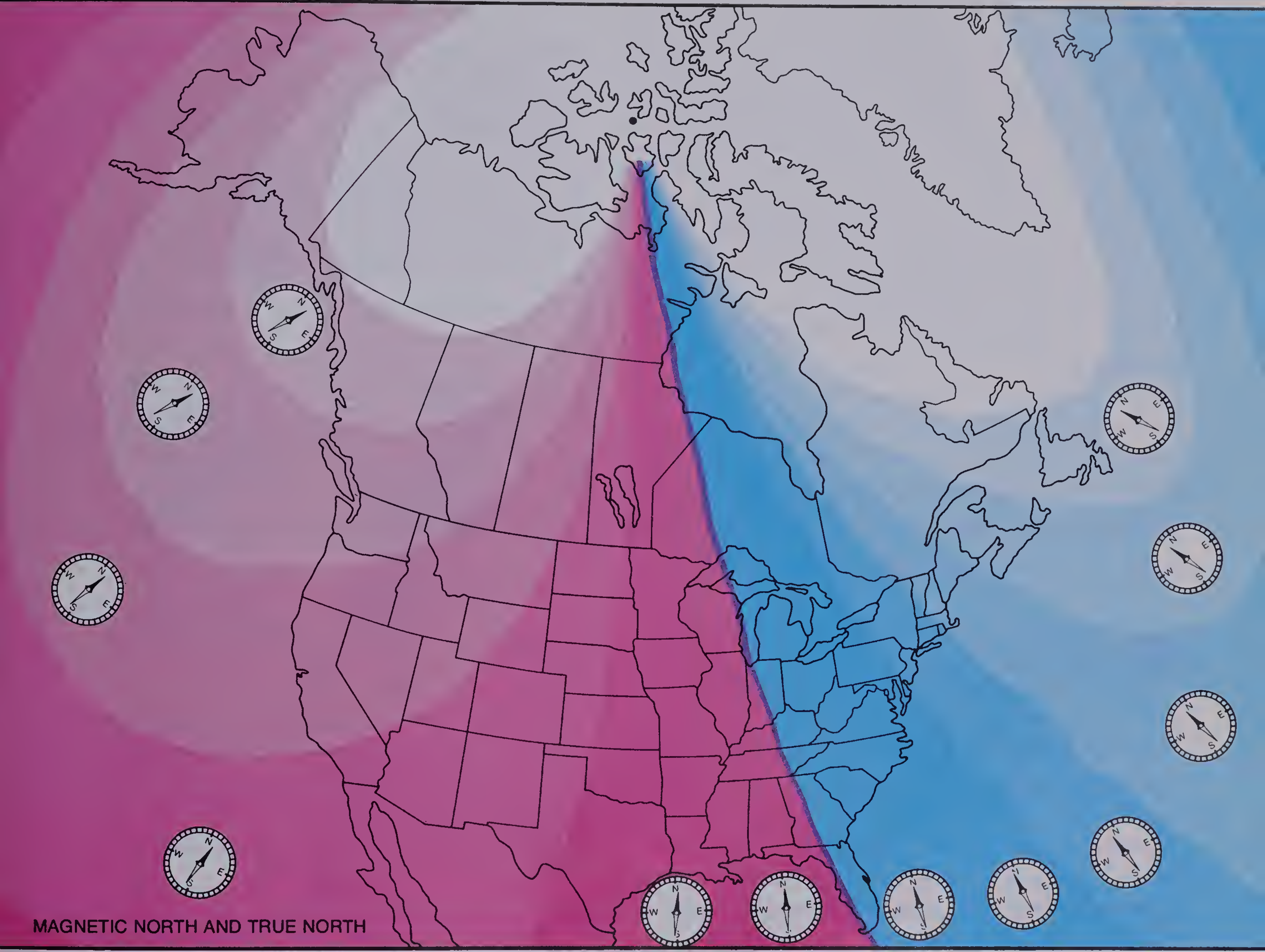
Where you live, does a compass needle point to true north? Or does it point toward the east or west of true north?

Finding true directions. Suppose you plan to use a compass on a hike. Then you should know the difference between magnetic north and true north in your area.

To find this difference, first locate your area on the map. In which color band do you find it? Study the compass in this color band. Note the difference between true north (shown by "N") and magnetic north (shown by the compass needle). *Make a record of the difference by drawing an exact copy of the compass.* Take it along with you on your hike.

Now, to find true directions, set your compass level. Turn it until the needle and the "N" on the dial are exactly as shown in your drawing. The north-seeking end of the needle should be on the same side of the "N." The difference between them should be exactly the same as in your drawing.

Then the "N" points out true north. The "S," "E," and "W" point out true south, east, and west. And "NE" points out true northeast; "SW" points out true southwest.



MAGNETIC NORTH AND TRUE NORTH

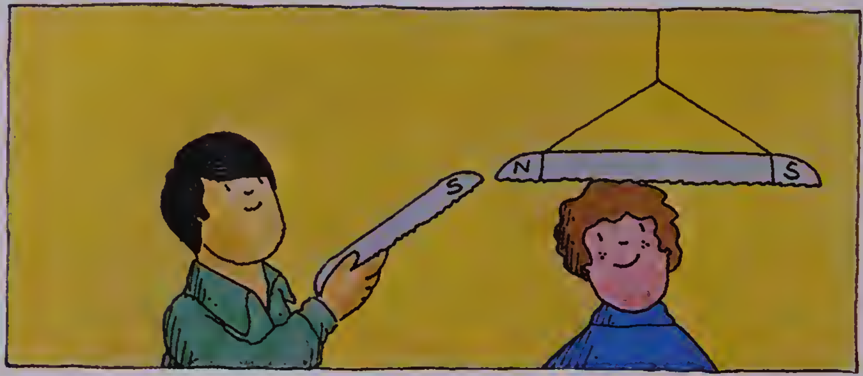
Interactions of Magnets LESSON 3

Two boys wanted to find out how magnets affect each other, or *interact.* First, they magnetized two hacksaw blades. Then they hung the blades on threads. They hung the blades far apart, and far away from things made of iron or steel.

The boys waited until the blades came to rest. Then, they marked the north-seeking and south-seeking poles of each magnet.

Next, one boy took down one of the blades. He brought it close to the other blade that was still hanging.

In this way, the boys tested how the two blades interacted. They watched to see how the different poles interacted. What do you suppose happened? Did two poles always attract each other? Or, did one sometimes push away, or *repel,* the other?



SOMETHING TO TRY

How do the poles of magnets interact?

You can easily find out. Use two magnetized hacksaw blades or other magnets. The blades or magnets should be about the same size and strength. The poles of each magnet should be marked.

Hang one from a thread so it can turn freely. Now bring one magnet close to the other. Do their poles attract or repel? Keep a record of what you find.

Test other pairs of magnets in the same way. Try several different kinds, such as magnetized needles and stronger bar and U-shaped magnets. What do you find after you test the magnets?

What kind of interaction takes place between

- two north-seeking poles?
- two south-seeking poles?
- a north-seeking pole and a south-seeking pole?

Forces at a distance. You have seen that magnets and certain materials, such as iron and steel, pull on each other. You also have seen that magnets pull or push on other magnets.

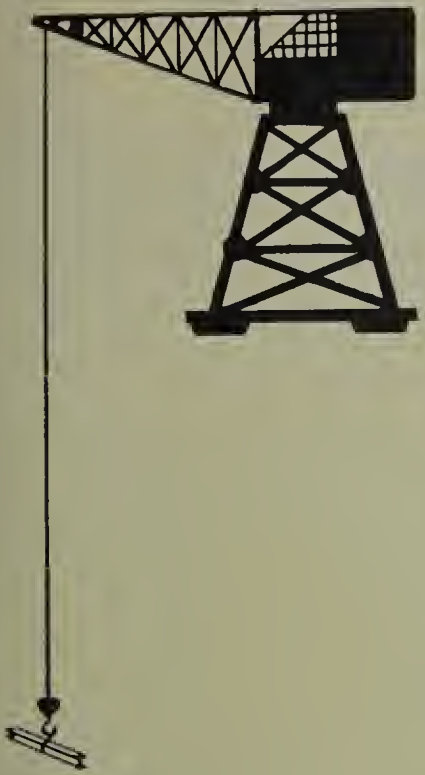
Pulls and pushes are called *forces*. There are a great many forces acting all around us.

Look at the drawing of the crane. The crane pulls on an object. The pull of the crane is acting through the cable.

Now look at the drawing of the woman playing shuffleboard. She also causes a force. What is the push of the woman acting through? What other examples can you give of pushes or pulls that act at a distance through solid objects? Which of these forces acts at the greatest distance?

Forces also may act at a distance through liquids and gases. For example, water from a garden hose can knock down flowers. And you can blow out a candle from across the table.

What are some other examples of forces that act at a distance through liquids and gases? Which of these forces acts at the greatest distance?



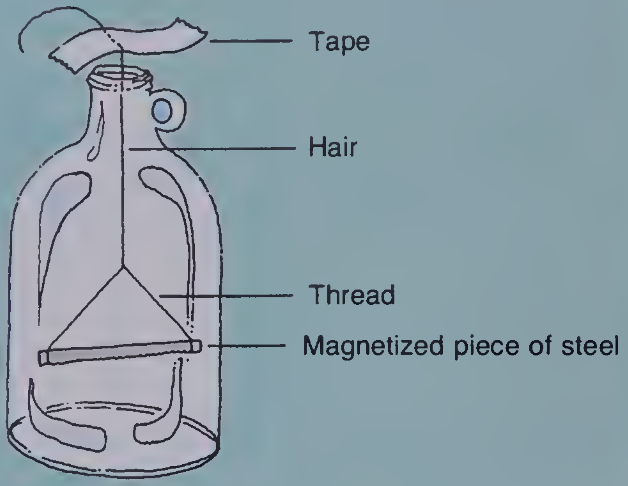
Magnetic forces. Magnetic forces, too, can act at a distance. But they do not need a solid, liquid, or gas to carry the force. They can act through empty space.

For example, a magnet and a piece of iron can pull on each other without touching. Also, two magnets can push or pull on each other, even though there is no matter between them. Their *like poles* (both north-seeking or both south-seeking) repel each other. Their *unlike poles* (one north-seeking and one south-seeking) attract each other.

True, there is usually air around magnets. But two magnets inside a closed jar still interact even if the air is pumped out.

The space around a magnet. How far apart can two magnets be and still interact?

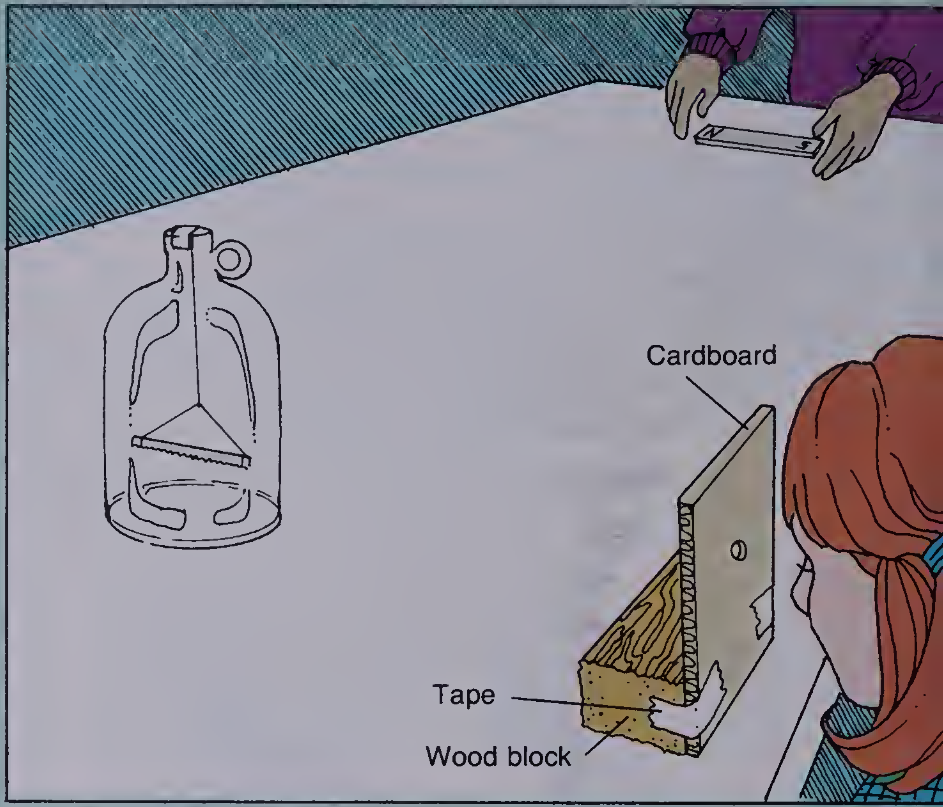
To find out, you can make a *detector* like the one shown below. It is a sensitive compass. You can use it to detect very weak magnetic forces.



Set your detector on a wooden table. Set it far away from things made of iron and steel. Do not move it even slightly. In time, the magnet will stop swinging.

Now see how far away another magnet can be from the detector and still affect it. Use the strongest magnet you have. Lay it gently on the table. Leave it there until the detector magnet stops swinging.

Then turn the magnet on the table around, end for end. Does this make the detector magnet move, even slightly? Look closely, but be careful not to shake the table.

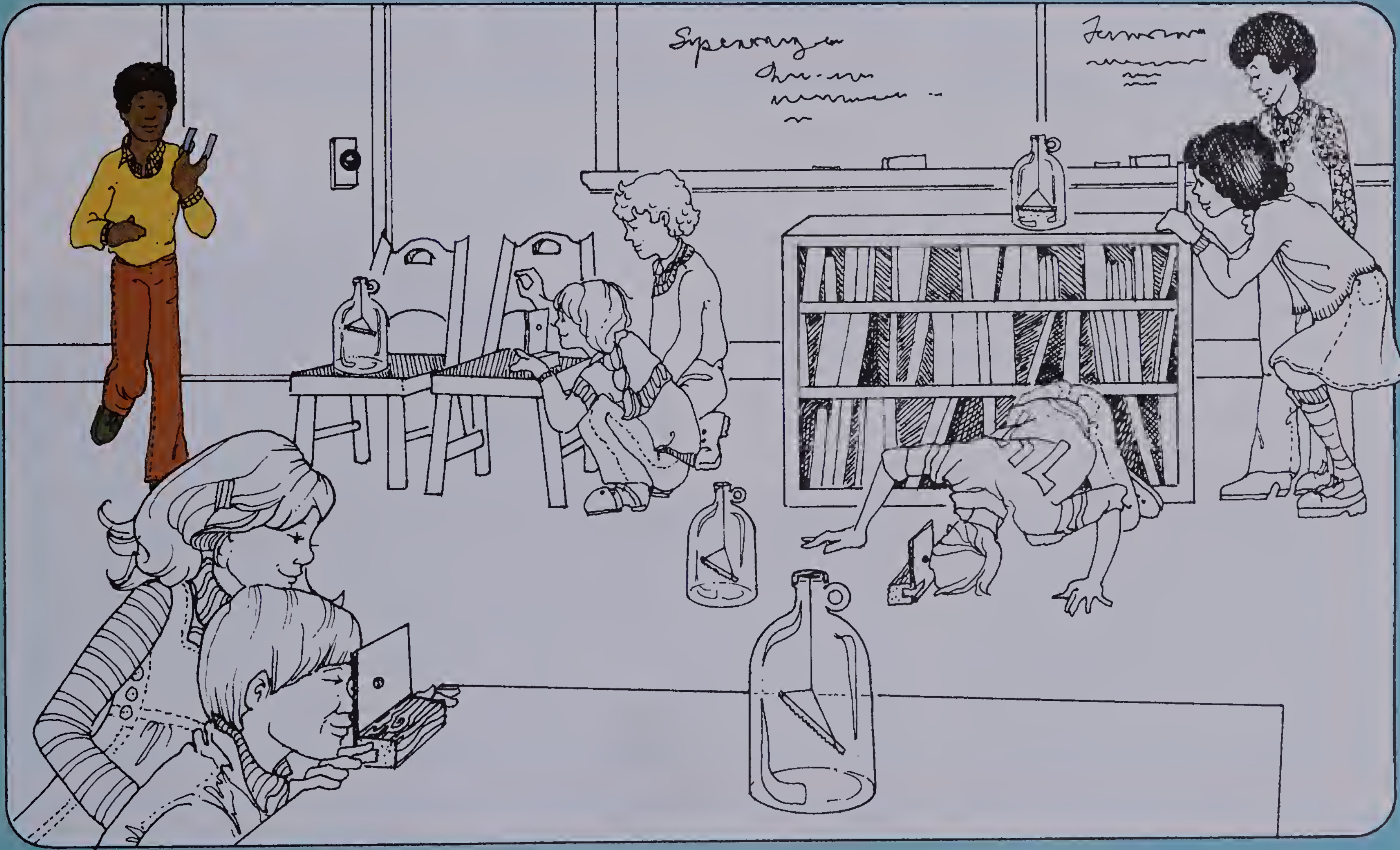


Try this several times, with the strong magnet farther away from the detector each time. How far away must it be before it no longer affects the detector magnet?

A peephole in a stand will help you tell whether the detector magnet turns. You can make a peephole in a piece of cardboard. Tape the cardboard to a block of wood. Now look through the peephole at the threads from which the magnet hangs. Move the stand until you see one thread directly in front of the other. Then you will be able to notice the slightest movement of the detector magnet.

Magnetic fields. You and your classmates might make several of these detectors and set them around the classroom. If you do this, you will find that a very strong magnet can affect all of the detectors at once. This shows that the force of a magnet can be very strong—so strong that it can be detected in all directions around the room.

All places where this force can be detected lie in a *magnetic field*. A magnetic field is found in all the space around a magnet. It is found in every direction. Near a magnet, the field is strong. Far from a magnet, the field is weak. For this reason, it may be hard to detect the force of a magnet from very far away.



Why does a magnetic compass work? The earth can be thought of as a giant magnet. It has two magnetic poles—a north magnetic pole and a south magnetic pole. Can you locate them on a globe?

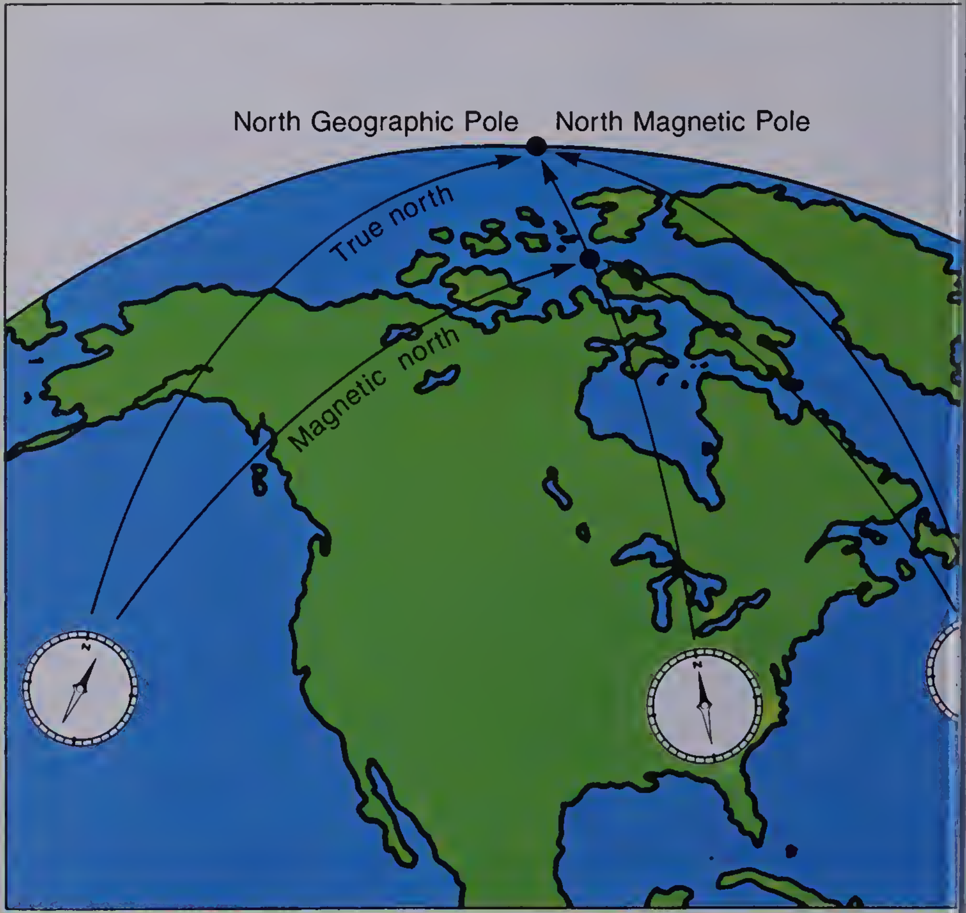
The earth and a compass needle interact the way two magnets interact. Their like poles repel each other. Their unlike poles attract each other.

This is what makes a compass needle show direction. It turns because of interaction with the earth. The compass needle's magnetic field and the earth's magnetic field interact. The compass needle lines up as closely as it can with the earth's magnetic field.

But why, in most places, does a compass needle not point to true north?

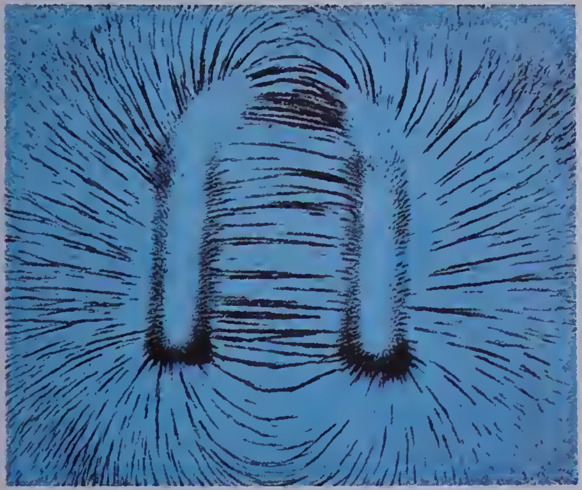
You likely know about the earth's geographic poles—the North Pole and South Pole. On a globe, you can see that they are not the same as the magnetic poles. For this reason, in most places, true north is not the same direction as magnetic north.

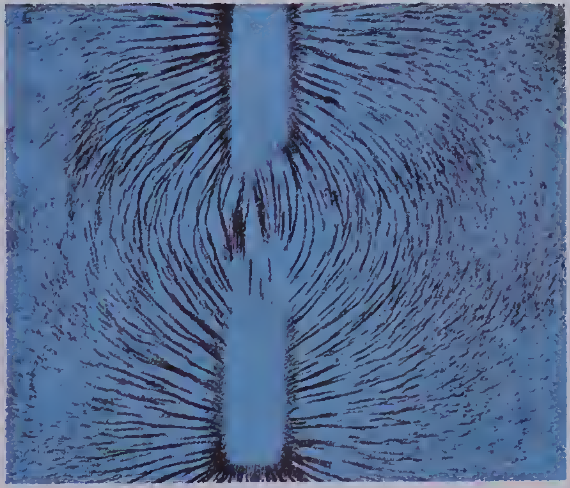
Everywhere on the earth, true north is in the direction of the geographic North Pole. Magnetic north, however, is more nearly in the direction of the north magnetic pole. In most places, a compass needle cannot point in the direction of both true north and magnetic north. In which direction does it point?

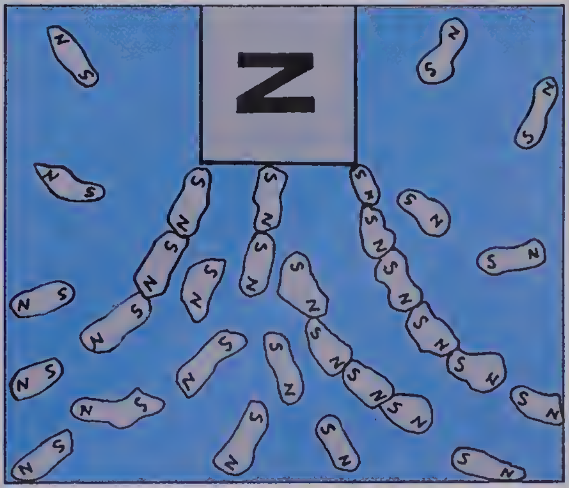


What is the shape of magnetic fields? When placed in the field of a magnet, bits of iron make interesting designs. They usually form strings or lines. These lines show the shape of the magnetic field.

However, a magnetic field does not have real strings or lines in it. Instead, the field causes the bits of iron to become tiny magnets. The unlike poles of these tiny magnets attract each other. Their like poles repel each other. Together these tiny magnets line up in the magnetic field of the large magnet. And their poles point toward the opposite poles of the large magnet. You can observe this for yourself.







Making magnets. Larger pieces of iron and steel also become magnets when placed in magnetic fields.

This helps to explain why a magnet and a nail attract each other. When placed in the field of a magnet, the nail itself becomes a magnet. Then there are two magnets. Their unlike poles are close together. And so, they attract each other.

This also explains why you can make a magnet of a steel object. It becomes magnetized just by being in the field of the magnet. But stroking it with one pole of the magnet is even better. Then you bring every part of the object into the strongest part of the magnetic field.

SOMETHING TO THINK ABOUT

A tall metal cabinet is a large "piece" of steel. It is located in a magnetic field—the magnetic field of the earth. Would you expect it to be magnetized? Do you suppose that it has a north-seeking pole and a south-seeking pole?

How could you tell whether it is magnetized? How could you find out where its poles, if any, are located? Try out your ideas.

Magnets That Use Electricity LESSON 4

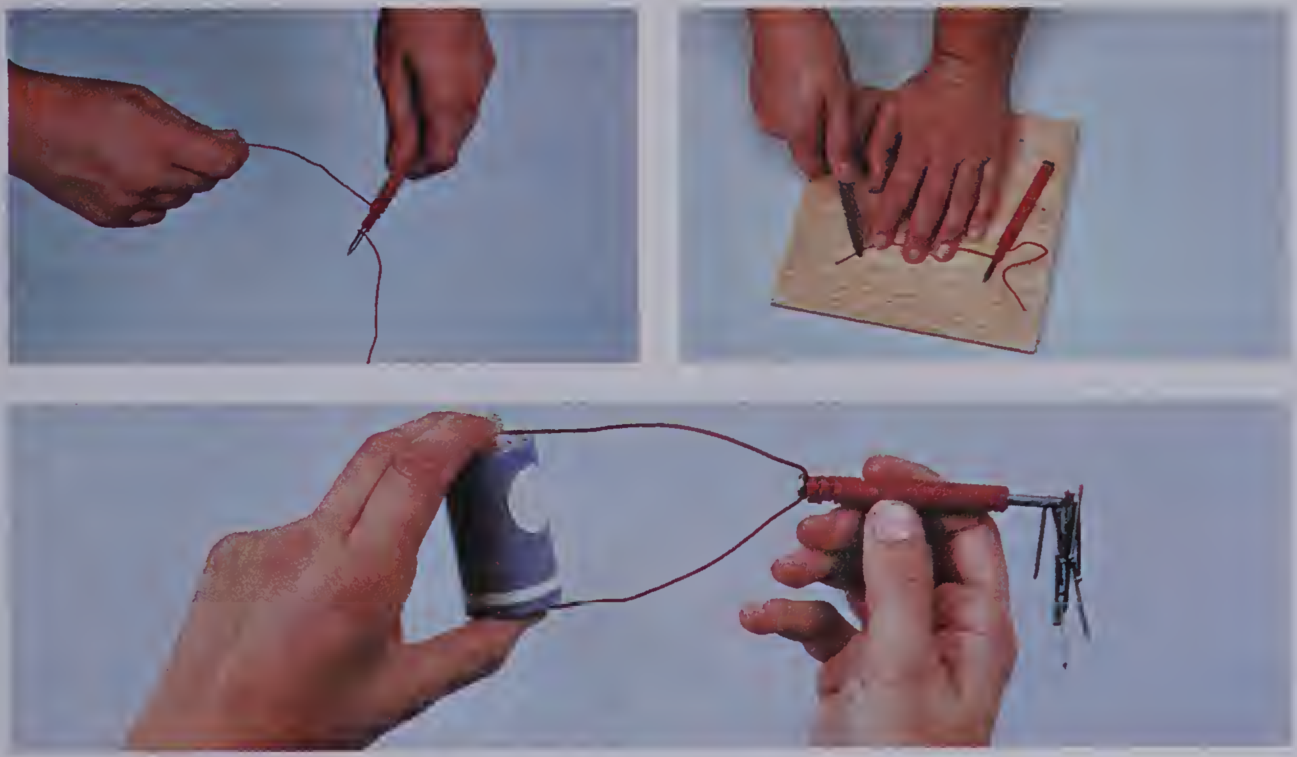
Some of the strongest and most useful magnets of all are made with electricity. Magnets like these are called *electromagnets*.

You can easily make an electromagnet. Start with a large iron nail or bolt. Also get a flashlight cell and a long piece of covered copper wire. Wind the wire many times around the nail or bolt. Scrape the covering off both ends of the wire until the metal is bare.

Then connect one end of the wire to the flashlight cell. Hold the other end to the bottom of the cell. Now test the nail. See whether or not it has become a magnet. What do you find?

Do not hold the wire to the cell for more than a few seconds at a time. Remove it at once if the wire gets warm. And do not hold the wire to the cell too often. Otherwise the cell will soon become weak.

Safety Note: *Never connect an electromagnet that you have made to an electric outlet! This is dangerous. You could get a shock or burn. Or you could start a fire.*



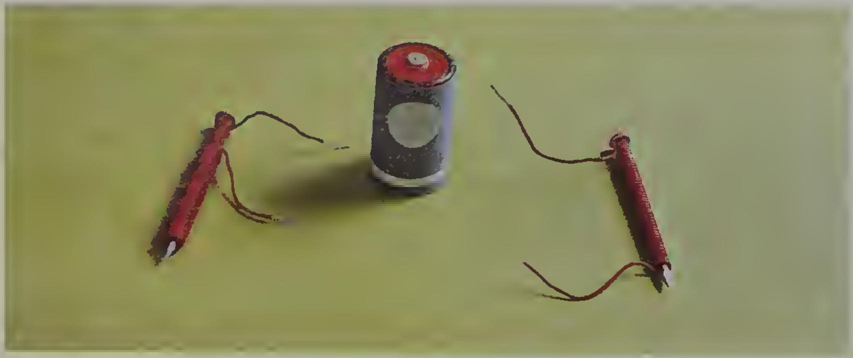
SOME THINGS TO TRY

1. How can you make a strong electromagnet?

Follow the directions on page 157. You can try different kinds and lengths of wire. You can also try different objects to wind the wire around.

After your electromagnet is made, test it. Count how many nails it can pick up. How many can your classmates pick up?

Keep all the tests fair. Have everything the same except the different electromagnets. Use equally fresh, strong cells. Use only nails of the same size.



2. Why are some electromagnets stronger than others?

First, list the things you think might make a difference in how strong an electromagnet is. Next, make a pair of electromagnets. Make them alike in every way but one—one of the things on your list.

Then, measure the strength of each. Which one is stronger? What seems to make it stronger?

3. How well does an electromagnet stay magnetized after being disconnected?

While connected to a flashlight cell, how many nails can an electromagnet pick up? Disconnect it. Now, how many nails can it pick up?

In this way, test electromagnets made with different iron or steel centers. After being disconnected, do some electromagnets keep their magnetism better than other electromagnets?

4. Do electromagnets have poles?

Connect an electromagnet to a flashlight cell. With a compass, can you find any poles? Be careful not to get the compass too close to the electromagnet. The electromagnet might reverse the poles of the compass needle. Then it would point in the wrong direction.

Reverse the cell connected to the electromagnet. Again, with the compass, look for poles. When you do this, what do you find?

Electric motor

Radio speaker

Doorbell

Crane

Uses of electromagnets. Electromagnets can be very strong—stronger than any other kind of magnet! They can be turned on or off quickly. Their strength can be changed easily. And their poles can be reversed.

For these reasons, electromagnets have many uses. For example, cranes use electromagnets to pick up heavy pieces of iron and steel. Door chimes and doorbells ring when hit by small iron hammers that are attracted by electromagnets. Electric motors spin because electromagnets inside them interact. And, because of electromagnets, radio and television speakers vibrate. This is how they produce sound.

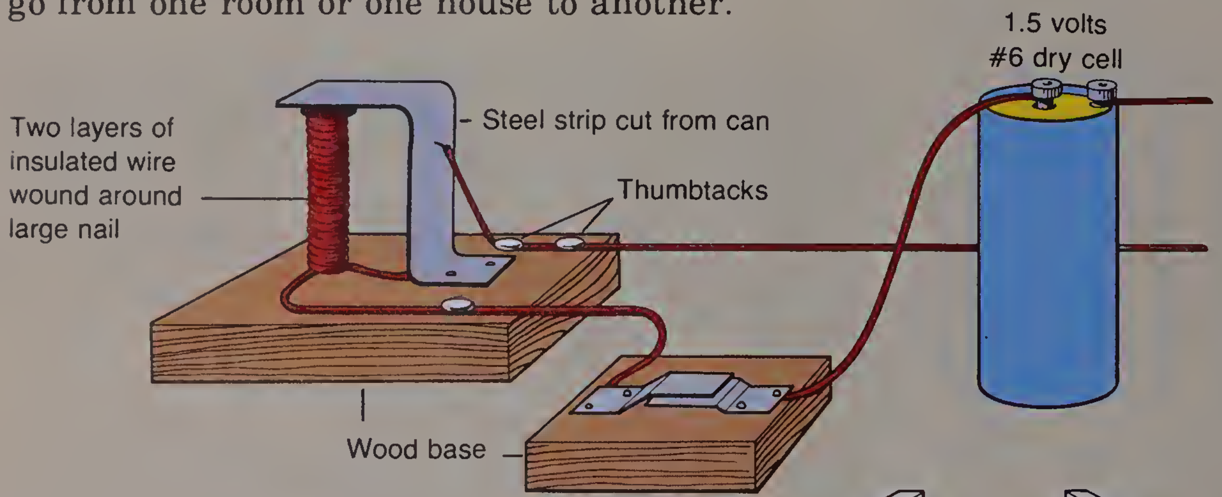
Electromagnets in telephone and telegraph. One of the most important uses of electromagnets today is in the telephone. But before telephones, people used the *telegraph*. It also used electromagnets. The "tele" in these words comes from the Greek word for "distance." What do you think "graph" and "phone" mean?

One kind of simple telegraph uses a buzzer and switch, or "key," and a dry cell. You can make a simple buzzer like the one shown. It has an electromagnet. Two of these groupings can be connected by wire to make a circuit. The wire may go from one room or one house to another.

The second drawing shows the circuit connected. With this circuit you can send messages back and forth. You can use the Morse code. The person receiving the message must hold down, or "close," his or her key. Why do you suppose this is necessary?

To make a "dot"—a short buzz—press the key for a very short time. To make a "dash"—a longer buzz—hold it down a little longer.

In this way you can send letters. Letters separated by short pauses can spell out words. And words can make messages.



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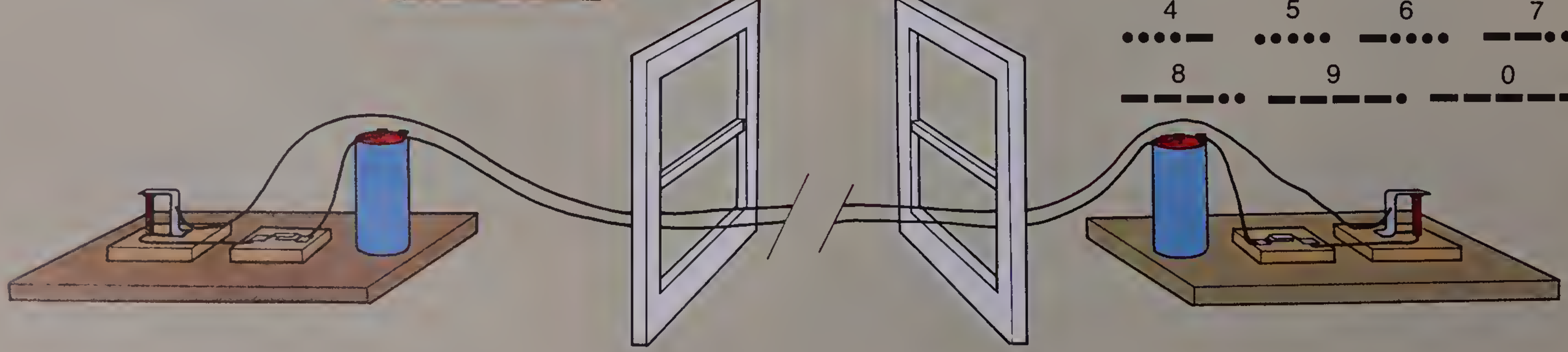
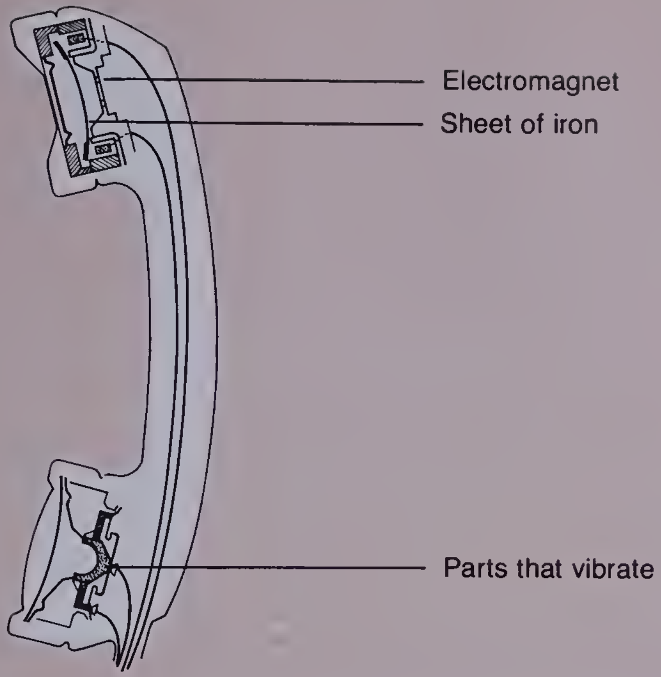




How telephones work. When you dial a friend's number, you connect your telephone with your friend's. The two telephones form a circuit. Electricity flows through this circuit.

When you speak, the sound makes parts in your telephone vibrate. The vibrations cause rapid changes in the flow of electricity. These changes carry your voice.

Inside each telephone is an electromagnet. It is connected in the circuit. When the electricity flow changes rapidly, the electromagnet's strength changes rapidly. Close to the electromagnet is a thin sheet of iron. When the electromagnet changes strength rapidly, the iron sheet vibrates rapidly. These vibrations sound much like your voice to your friend.

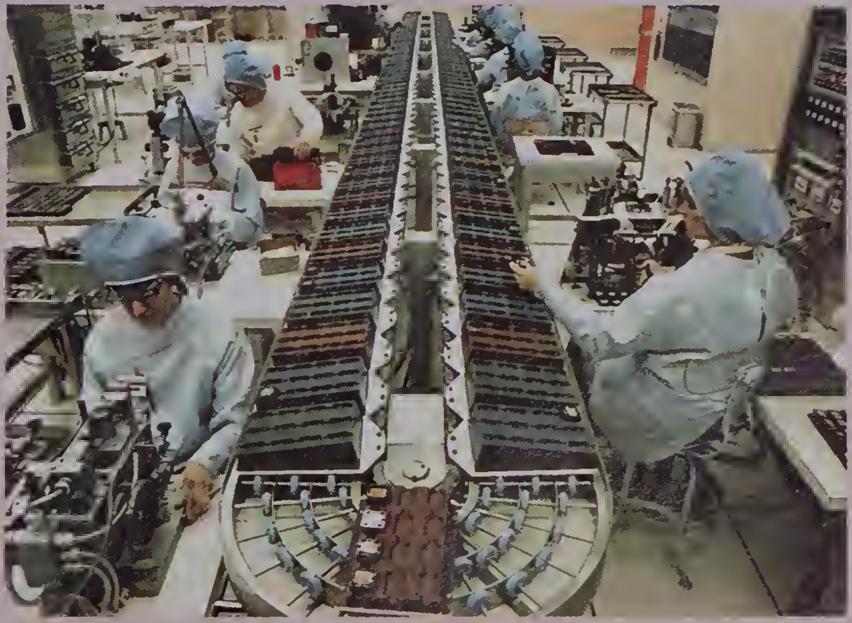
JOBS Using Science

Today there are millions of telephones in Canada and the United States. Thousands of people are needed to make all these telephones and to keep them working.

Factory workers make the many parts of telephones. Some wind the electromagnets. Others connect the parts together. Not all of this work is done by hand. Machines do much of it.

Installers place telephones in homes and offices. Other people string the wires. They also repair wires when they are knocked down.

Other workers put together the switches. They also keep the switches in working order. Switches make it possible to connect a telephone to almost any other telephone.



Ideas for REVIEW

- Magnets attract mostly iron and steel, but they also attract some other materials.

- When a magnet attracts an object, the object also attracts the magnet with an equal force.
- A magnet can act through most materials, but it also can act through empty space.
- The force of a magnet is strongest at certain places called poles.
- The poles of a magnet are named for the poles of the earth to which they tend to point.
- Every magnet has two unlike poles.
- Like poles repel each other and unlike poles attract.
- A magnet is always surrounded by a magnetic field.
- A compass shows direction because its magnetic field interacts with the magnetic field of the earth.
- When placed in the field of a magnet, magnetic material tends to become magnetized.
- An electromagnet can be made by having electricity flow through a coil around a piece of iron or steel.
- Electromagnets can be turned on and off, can be made very strong, and can have their poles reversed quickly.

TEST Your Understanding

A. Write the numbers 1-8 on a piece of paper. Choose a word from the following list that makes each sentence correct. Write the word next to the correct number on your piece of paper. Not all the words are used. *Do not write in this book.*

attracts
repels
brass
iron
compass
electromagnet
force
glass
lodestone
pole

1. The word _____ means a push or a pull.

2. A _____ is a place on a magnet where its attraction is strongest.

3. One metal that is not magnetic is _____ .

4. A kind of matter that both magnetism and light pass through is _____ .

5. A _____ is a naturally magnetized piece of iron ore.

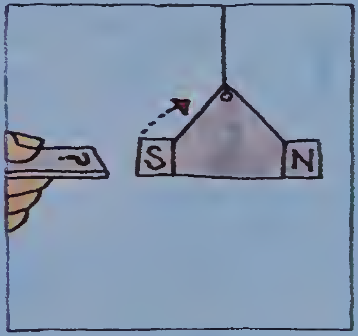
6. A magnet used in a telephone or a telegraph is an _____ .

7. A _____ is an object that has a freely turning magnet.

8. The north pole of a magnet _____ the south pole of another magnet.

B. Write the numbers 9-12 on your paper. Now look at each drawing. Does the question mark in each drawing show a north-seeking pole or a south-seeking pole? Write your answer next to each number.

9.



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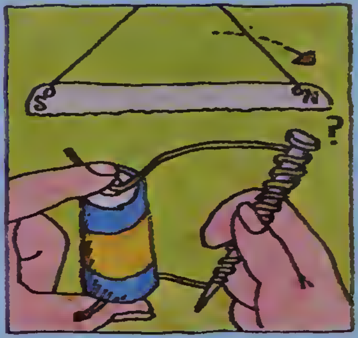

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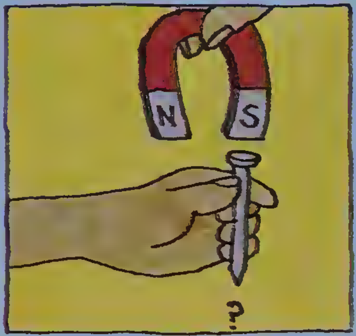

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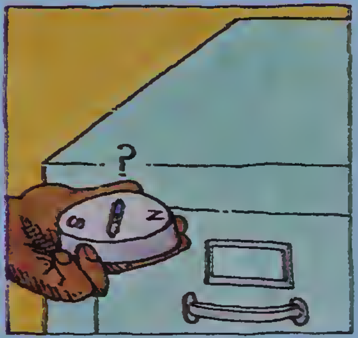


C. Write the numbers 13-14 on your paper. Now answer the following questions.

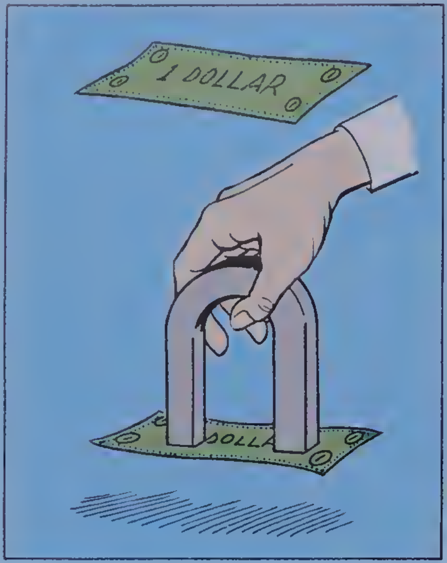
13. What might cause a magnet to lose its strength?

14. Where is the north magnetic pole of the earth located?

PROBLEMS

1. Why do each of these things happen?

a



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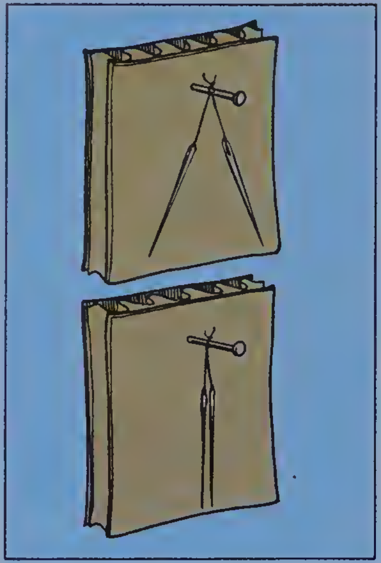
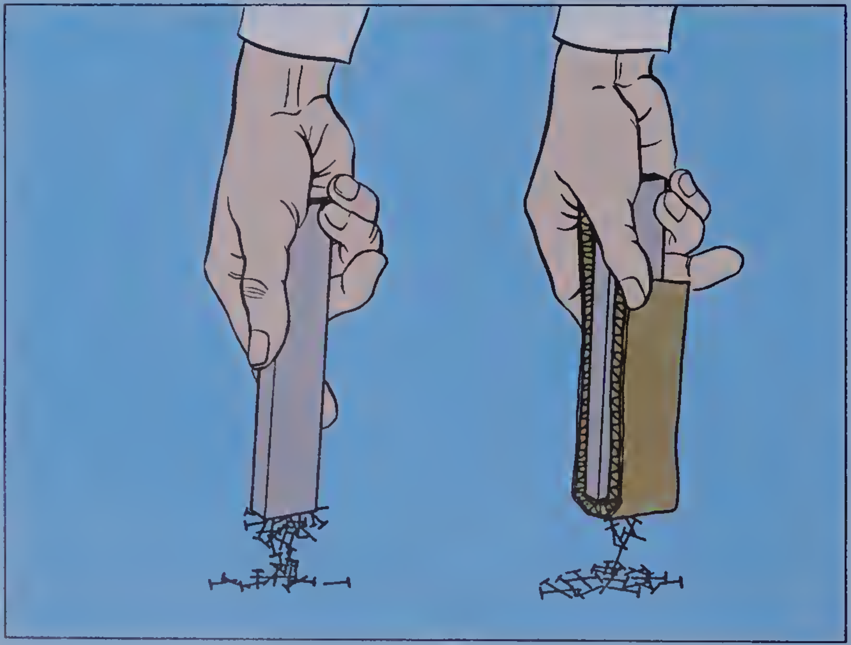
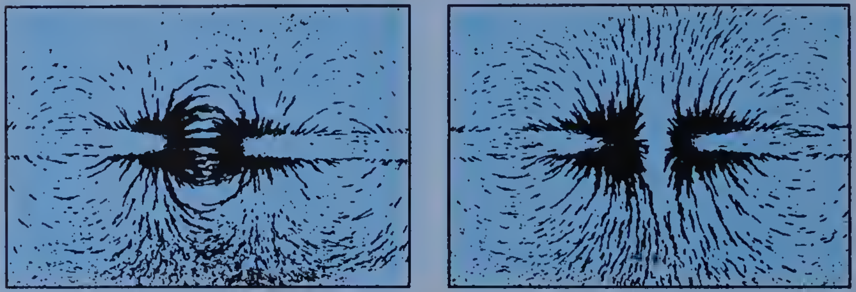


c

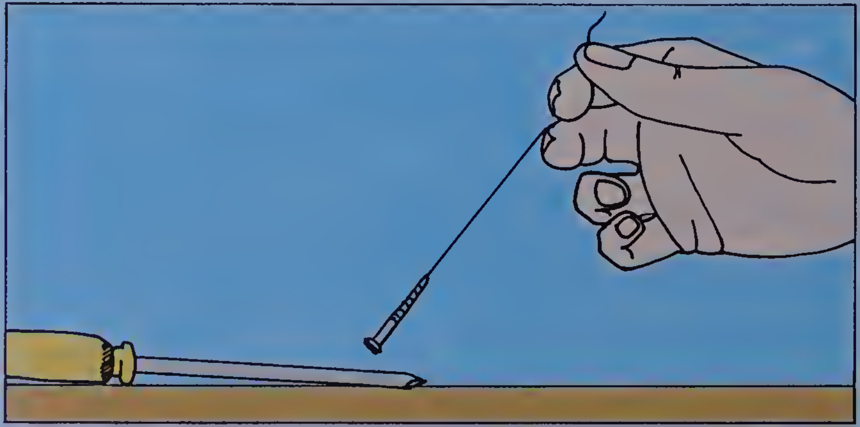


2. Each drawing below shows a piece of cardboard with many bits of iron on it. What do you suppose is under each piece of cardboard? Why are the patterns different?



3. Suppose you hang a screw on a thread. Then you bring a screwdriver close to it. They attract each other.

Would this happen because the screwdriver is magnetized? Could you be sure? Could the screw be magnetized instead? Could both be magnetized? How could you tell?



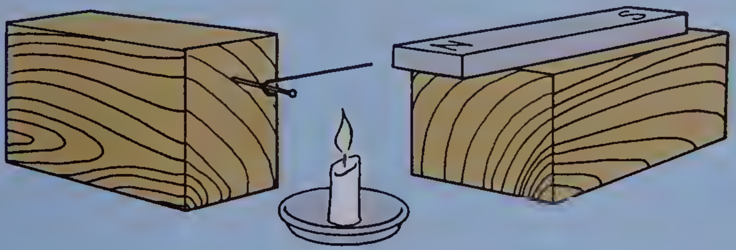
FIND OUT on Your Own

1. Is iron or steel magnetic when it is hot?

Bend a tiny hook in one end of a 5-cm piece of thin iron or steel wire. You can use one wire from a picture cord wire.

Hang the hook on a pin stuck into a block of wood. Place a strong magnet so it pulls the wire straight out. Make sure the wire does not touch the magnet.

Heat the wire until it becomes red hot. What happens? What happens when the wire cools off? **Safety Note:** *Don't try this unless an adult is present.*



2. Can you make copper become magnetic?

Stroke a piece of copper with a strong magnet. Does the copper become magnetized, even slightly?

Now cut two strips from a thin aluminum pan. Fasten them with rubber bands to a flashlight cell. Fasten one to the top of the cell and the other to the bottom. Do not let them touch each other. This is shown at the right.

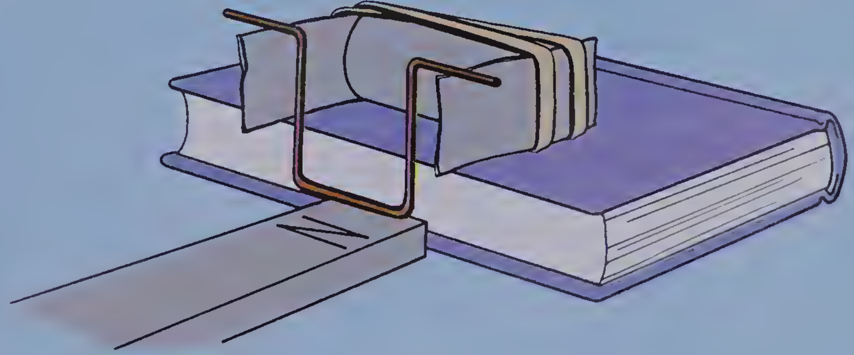
Rest the flashlight cell on a book, with the aluminum strips sticking out over the edge. Then lay a strong magnet near the book. Have one pole below the space between the strips.

Next, get a piece of thin copper wire with no insulation on it. Bend it as shown in the drawing. Then rest it on the strips of aluminum so that it can swing freely. It should come very close to the magnet but should not touch it. What happens?

Lift the copper swing off the aluminum strips. Turn the magnet around. Place its other pole under the swing. Lower the swing back on the aluminum strips. What happens?

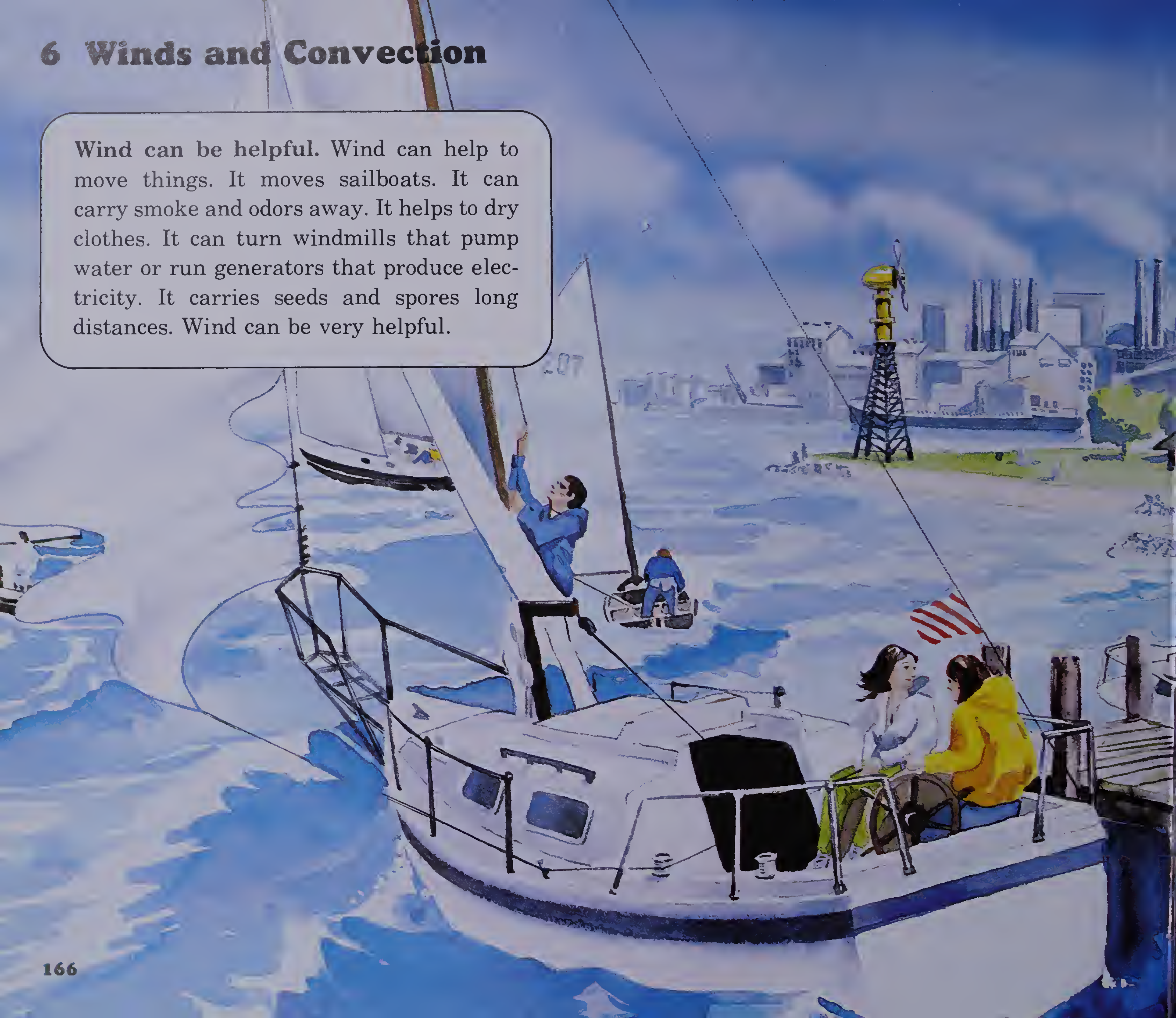
Note: Do not leave the swing on the aluminum strips for more than a few seconds. Otherwise the cell will become weak quickly.

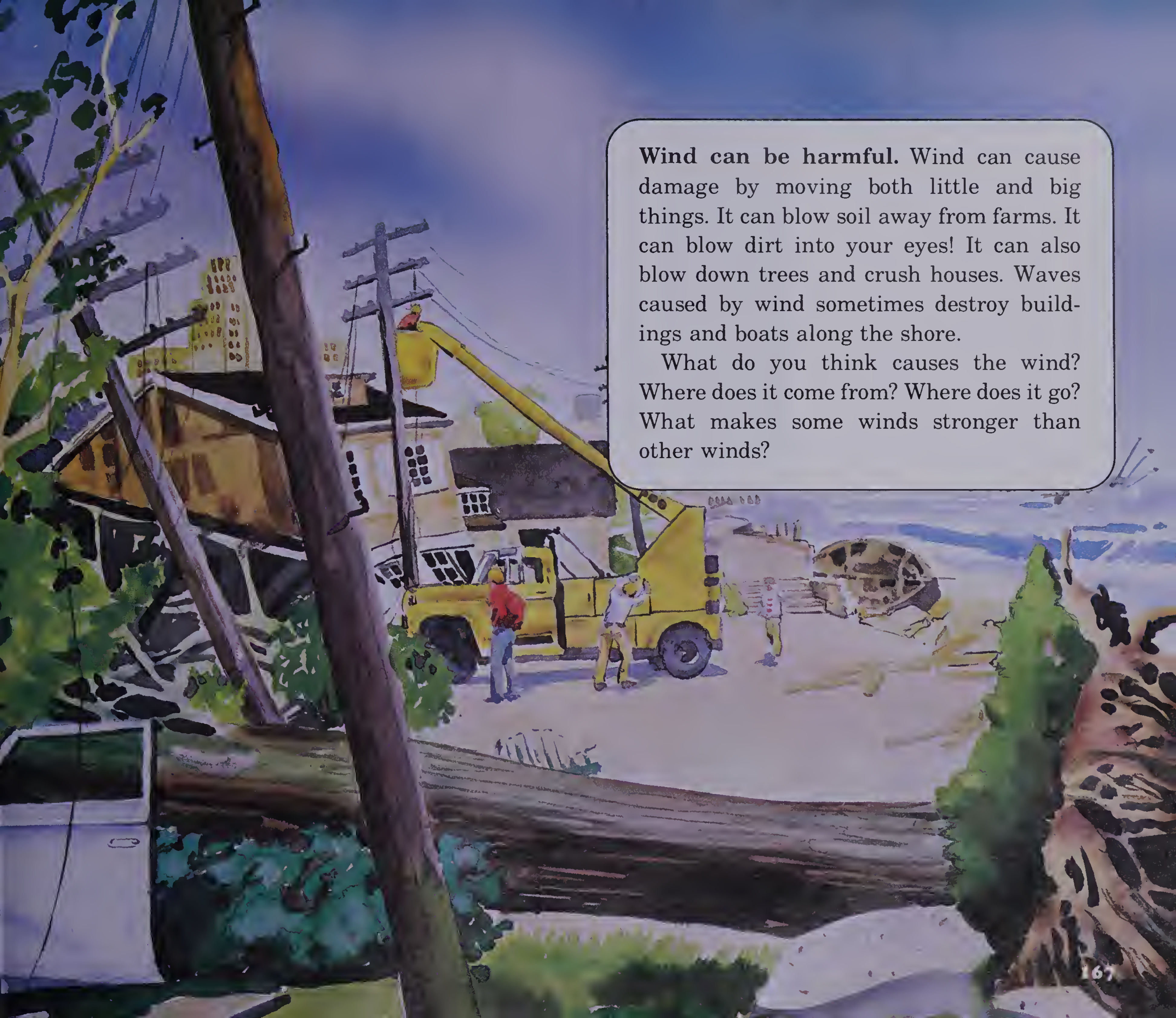
How can you explain what you observe? Is copper magnetic? Can you magnetize it? Can you cause it to have a magnetic field? How?



6 Winds and Convection

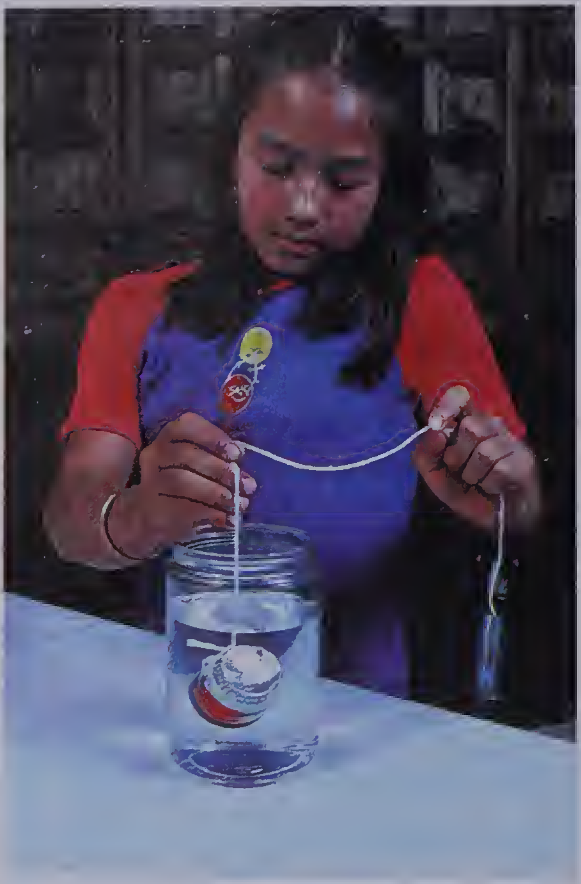
Wind can be helpful. Wind can help to move things. It moves sailboats. It can carry smoke and odors away. It helps to dry clothes. It can turn windmills that pump water or run generators that produce electricity. It carries seeds and spores long distances. Wind can be very helpful.

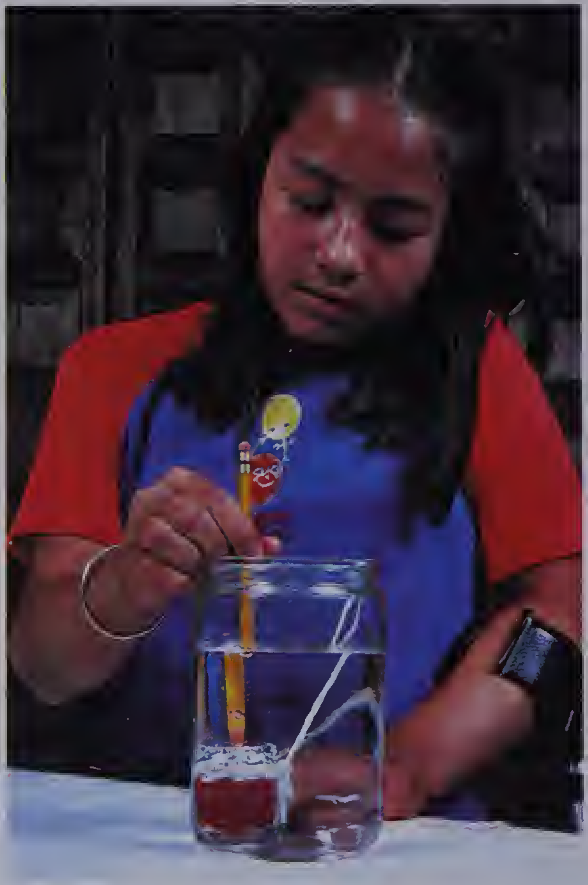




Wind can be harmful. Wind can cause damage by moving both little and big things. It can blow soil away from farms. It can blow dirt into your eyes! It can also blow down trees and crush houses. Waves caused by wind sometimes destroy buildings and boats along the shore.

What do you think causes the wind? Where does it come from? Where does it go? What makes some winds stronger than other winds?





SOMETHING TO TRY

Water and gases, such as air, are *fluids*. Find out what happens when a cold fluid and a warm fluid meet.

Fill a large, wide-mouth jar two-thirds full with cold water. Next, put three drops of food coloring in a baby-food jar. Fill the baby-food jar to the top with hot water. Cap it with aluminum foil. Hold the foil on tightly with rubber bands. Tie a string around the baby-food jar. Carefully lower it to the bottom of the large jar.

Wait until the water is still. Then punch two holes in the foil with a long pencil. Watch what happens.

Does colored fluid rise from only one, or both, of the holes? What do you think causes it to rise? How long will it keep rising? After a long time, what will the fluid in the large jar be like?

Suppose you had punched only one hole. Then what would have happened? Test your ideas and see!

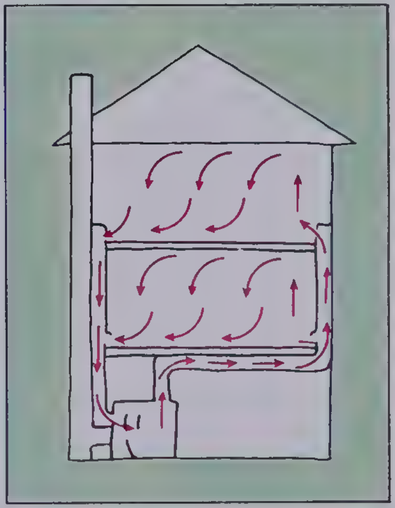
Convection. The colored water in the baby-food jar was warm. The water in the large jar was cold. Cold fluids tend to be heavier, or more *dense,* than warm ones. Cold, dense fluids tend to settle. They push warm, less dense fluids out of the way.

When you made two holes in the foil, cold, dense water settled into one of them. It pushed warm, less dense water up and out the other hole. (Why might it *not* have worked with only one hole?) A cold fluid pushing a warmer, less dense one away is called *convection*. Convection happens outdoors and indoors. It happens whenever one part of a fluid is warmer or colder than another part. Then the warmer part gets pushed up as the colder part settles beneath it.

When you open a refrigerator, cold air spills out. You can't see it, but you feel it on your feet. As cold air leaves the refrigerator, other air enters and takes its place. This movement is convection. Convection happens each time you open a refrigerator door.

When a candle burns, the energy from the flame warms the air around it. As the air becomes warm, it becomes less dense. Then colder air pushes it up and away. So the heat energy from the flame is moved, or *transferred*, to another place. Convection is an important way of transferring heat energy.

If the furnace in your home sends out hot air, hot water, or steam, then there is convection. How would you explain the direction of the arrows in the picture? What pushes the hot fluid up away from the furnace? What would cause smoke to go up a chimney instead of down?



SOMETHING TO TRY

Punch a hole in the bottom of a paper cup. Then put a piece of tape on the outside of the cup to cover the hole. You will remove the tape later.

Put three drops of blue food coloring in the paper cup. Fill the cup half full with water. Put it in a freezer. Do not take it out until it is solid.

Fill a large, wide-mouth jar nearly full with water. Set it where it won't be disturbed. Allow time for the water to become still.

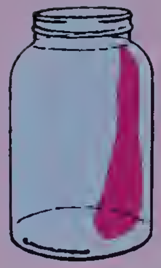
Then place a drop of red food coloring in the water at one side of the jar. Let it stand for a few minutes. What happens?

Now peel the tape from the bottom of the cup of blue ice. Stick one end of a strip of tape to the inside of the cup. Holding the tape, lower the cup part way into the water. Do this at the side away from the red drop. Do not disturb the water any more than you have to. Then fasten the tape to the jar to hold the cup in place. Watch what happens!

Is the blue liquid warmer or cooler than the water in the jar? Where does the red liquid go as the blue liquid sinks?

When temperature differences are great, convection takes place rapidly. In time, convection mixes the fluids. But before they are mixed thoroughly, convection fills the low spots with cold fluid. Warmer fluid gets pushed out of the way.

1



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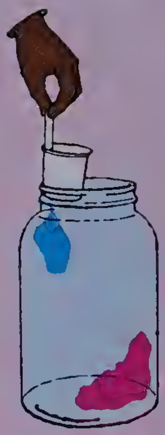

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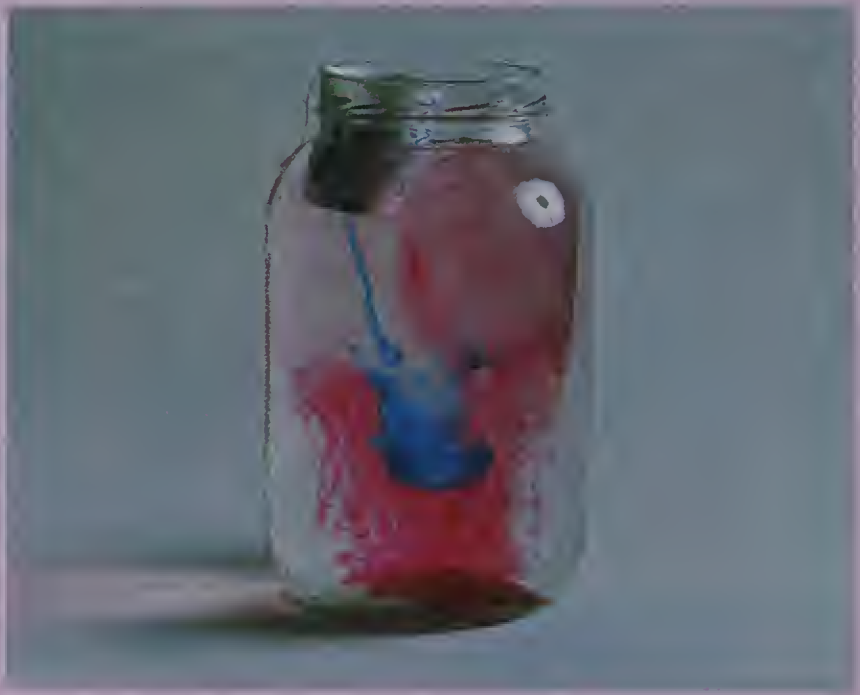


SOMETHING TO TRY

Suppose a warm layer of fluid is on top of a cold layer. Will convection take place? How easily?

With your teacher's help, fill one of two identical jars with cold water. Place the jar in a large, deep pan on a table. In the second jar, put several drops of food coloring. Fill this jar to the very top with warm water. Wet an index card on both sides. Then lay it over the mouth of the warm-water jar.

Hold the card firmly in place. Quickly turn the jar upside down. Be sure you hold the jar straight up, or vertically. Take your hand away.The card will stay in place, even though the jar is filled with water.

Set the warm-water jar directly on top of the cold-water jar. Be sure that the rims match. Then, while one person steadies the upper jar, carefully pull out the card. Watch what happens.

Does convection take place right away? Does either body, or mass, of water tend to replace the other? How long do you think these layers of water will stand without mixing? Make a prediction. Then wait and see!

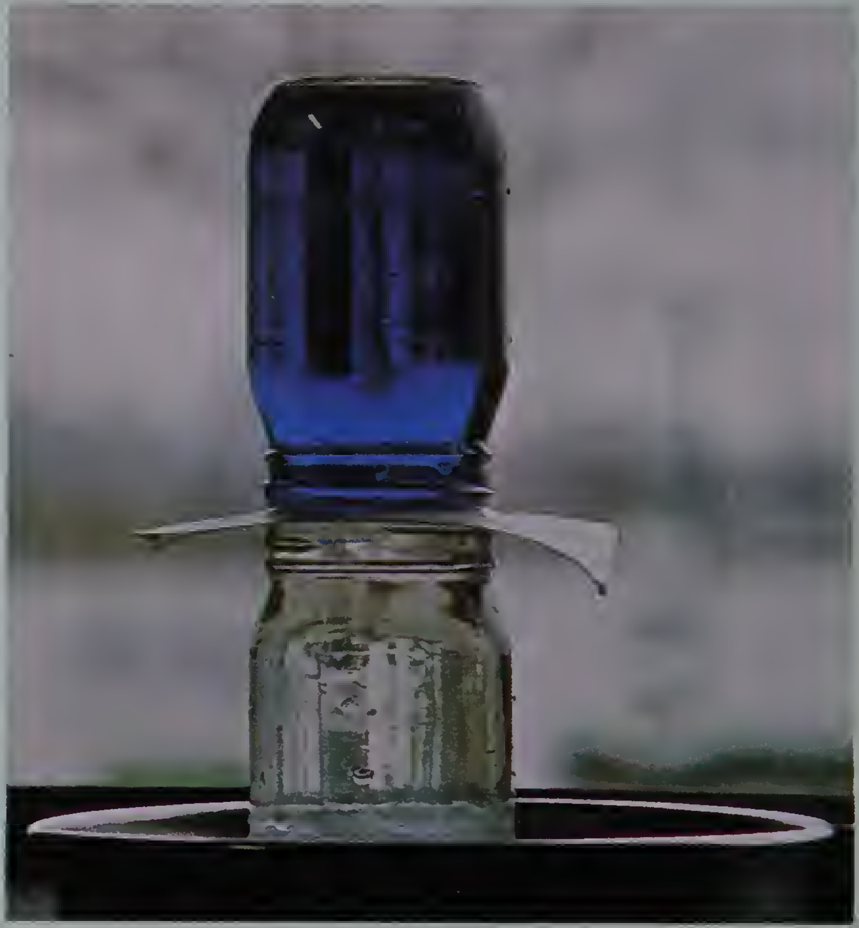
Warm over cold is stable. When a mass of warm fluid lies above a cold one, they tend to stay that way. They do not mix easily. There is almost no convection. Such a condition is called *stable.*

A warm layer of water resting on a cooler one is stable. A warm layer of air resting on a cooler one is also stable.

SOMETHING TO DO

Using the same two jars as before, fill one jar with warm water, and set it in a pan. Put a few drops of blue food coloring in the second jar. Then fill it to the top with cold water. Cover the cold-water jar with a card. Then turn the jar upside down, and set it on the warm-water jar. What do you think will happen when the card is removed?

With the help of a partner, remove the card. What happens? Was your idea correct? Why do you suppose cold over warm is called *unstable*?



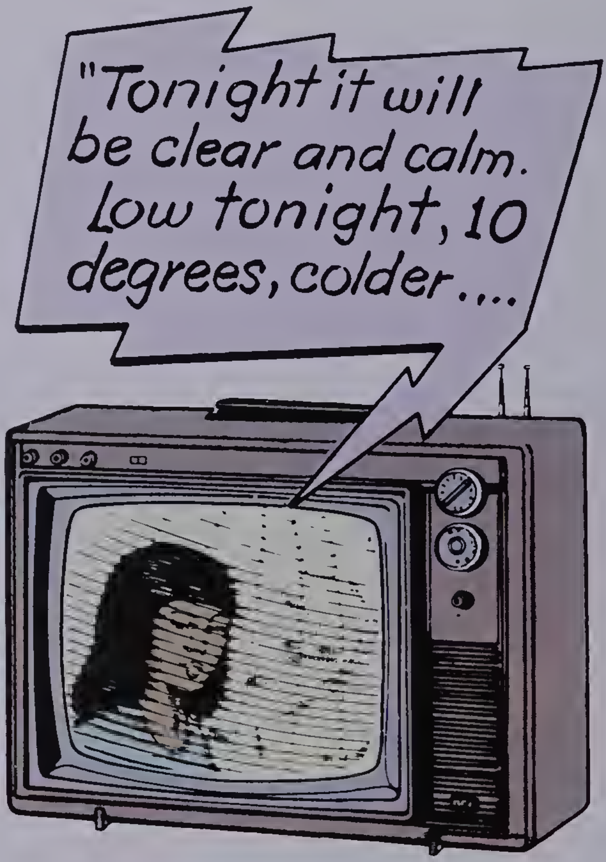
A stable weather condition. On nights that are clear and calm, cold air settles in valleys. As it settles, the cold air pushes under warmer air. Then the warmer air lies over the cold air. Warm air over cold air is a stable condition. It usually stays that way.

In stable air, smoke from chimneys and factories rises only a little bit before spreading out. Smoke and fog, or *smog,* may slowly form a sort of lid over a city. The air can be so stable that the smog is not blown away. In time, this can be serious. Breathing becomes difficult, and eyes begin to smart. Smog can even cause death for people with breathing problems.

As you can see, stable air does not always mean pleasant living.

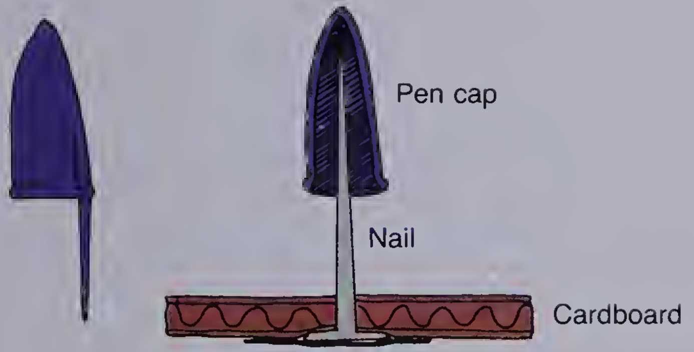
Unstable weather. A thunderstorm is evidence of unstable air. In a storm, rain and hail cool part of the air they fall through. When this air becomes cooler than the air around it, it sinks. This cool, sinking air from inside a thunderstorm may be felt far ahead of the storm. Have you ever felt that a thunderstorm was coming?

In winter, the sea may be much warmer than the air above it. The sea warms and moistens the air touching it. The warm, damp air becomes lighter. Cooler air around it sinks, causing the warm, damp air to rise. This overturning of air masses causes winds to blow and clouds to form. Clouds too, then, are evidence of unstable air.


"Tonight it will be clear and calm. Low tonight, 10 degrees, colder....

SOMETHING TO THINK ABOUT

Would this person be more likely to add ". . . in the valley sections," or ". . . on the hilltops"? Why do you think so?



SOMETHING TO MAKE AND TRY

Sometimes it is helpful to know what the wind direction is. The kind of weather we have often depends upon the direction of the wind. A *wind vane* shows the direction *from* which the wind comes. It points north if the wind comes from the north. And it points south if the wind comes from the south.

1. Make your own wind vane. Remove the plastic cap from a ball point pen. With a pair of scissors, cut the pocket clip off the cap. With tape, fasten a feather about 15 cm long to the top of the cap.

Push a sharpened 5-cm nail up through a piece of corrugated cardboard. Then tape the nail in place. Now place the cap and feather on the nail. Put a bit of clay on the point of the feather to balance it. Do this carefully. The feather should turn freely. If it does, it always will point into the wind.

2. Set your wind vane on the floor in front of a refrigerator. Be sure there are no drafts from open doors or windows. When all is still, open the refrigerator door. Which way does the feather point? From what direction must the air be moving?

Hold the wind vane in front, and near the top, of the refrigerator opening. Where does the feather point now? From what direction must the air be moving?

Air is seldom still. Try placing your wind vane at different places around you. Usually you cannot feel air moving. But your wind vane will show that air almost always is moving.

When you walk, you push air out of the way. Then air rushes in and fills the space you just left. This motion causes tiny winds. You can tell when they happen by watching your wind vane.

SOMETHING TO TRY

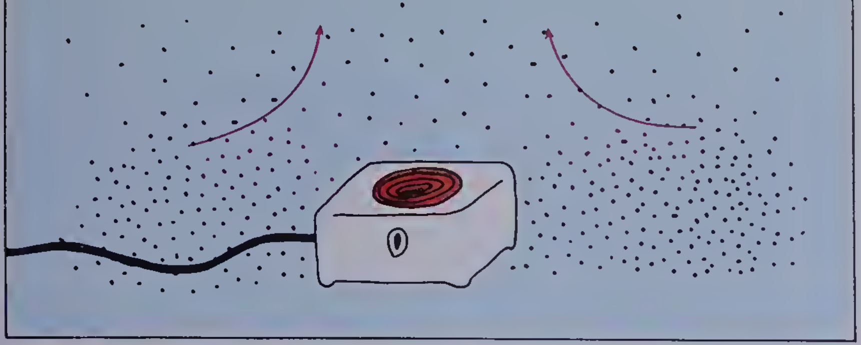
Set a wind vane on the floor and see which way it points. If it points toward the windows, in what direction must air be moving? Why do you think so?

If the air moves in one direction at the floor, in what direction must it move at the ceiling? Test your idea by holding the wind vane near the ceiling.

Hold the wind vane at different places around the room. Wherever you can, tape a paper arrow to show the direction of air movement.

When you have checked many places, try answering these questions:

- Where does the wind direction tend to stay the same?
- Where does the wind tend to change direction most often?
- Would you describe the air in your room as still or moving?



Winds Around Us LESSON 4

When air is warmed, it expands. When air is cooled, it contracts. Cooler air, above or beside warmer air, tends to settle under the warmer air. That pushes the warmer air out of the way, causing a wind. Warm air does not rise by itself. It is pushed by cooler air!

Air can move in any direction. However, when we think of wind, we mostly mean air moving sideways, or horizontally.

Burning something makes the air around it warmer. But there are other ways. Sometimes one land surface absorbs the sun's energy better than another. Then it gets warmer, and warms the air above it.

Such surfaces may be pavements, plowed fields, cities, and even whole continents. Or air may be warmed by a warm lake or sea. But not all surfaces are big. Air may even be warmed by cars, cats, and TV sets. The winds that result depend on the size of the surface, and how warm it becomes.

The earth's surface is not the same all over. It is high in some places, low in others. It is light in one place, dark in another. It is wet in one place, dry in another.

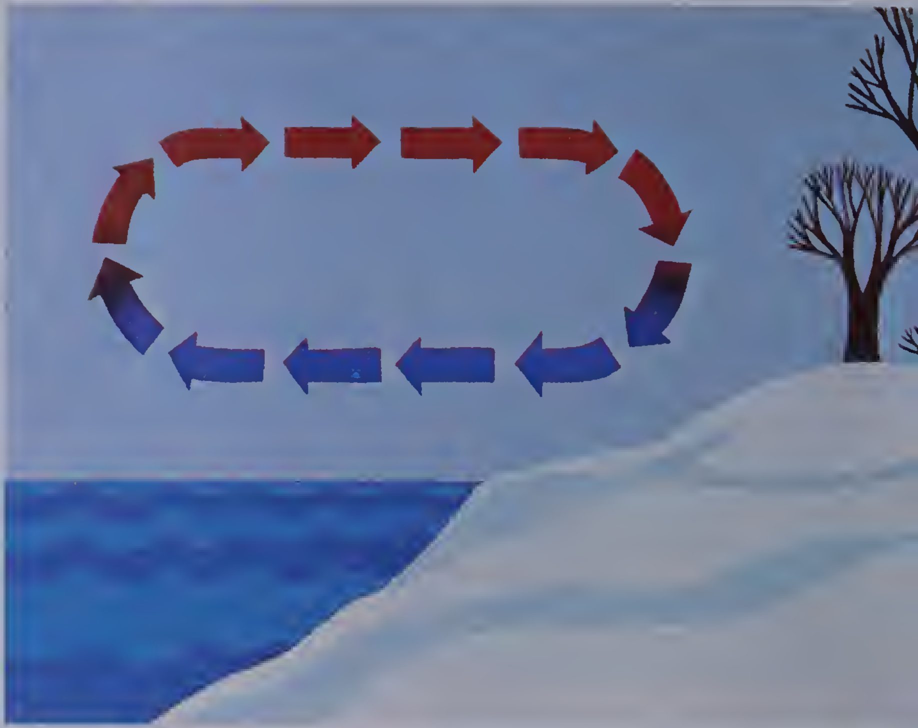
The earth's surface is different from place to place. So are the movements of the air above different places.

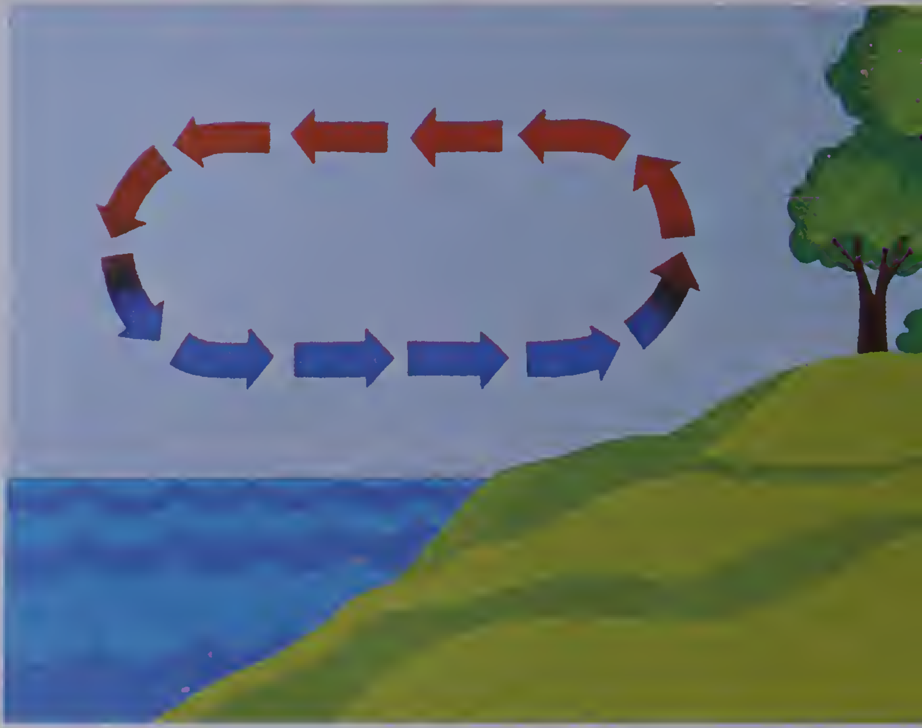
Winter and summer winds. In winter, the land may be much colder than the sea. This causes air to settle over the land and to flow under the air at sea. The warm air over the sea rises. Then the wind blows from land to sea.

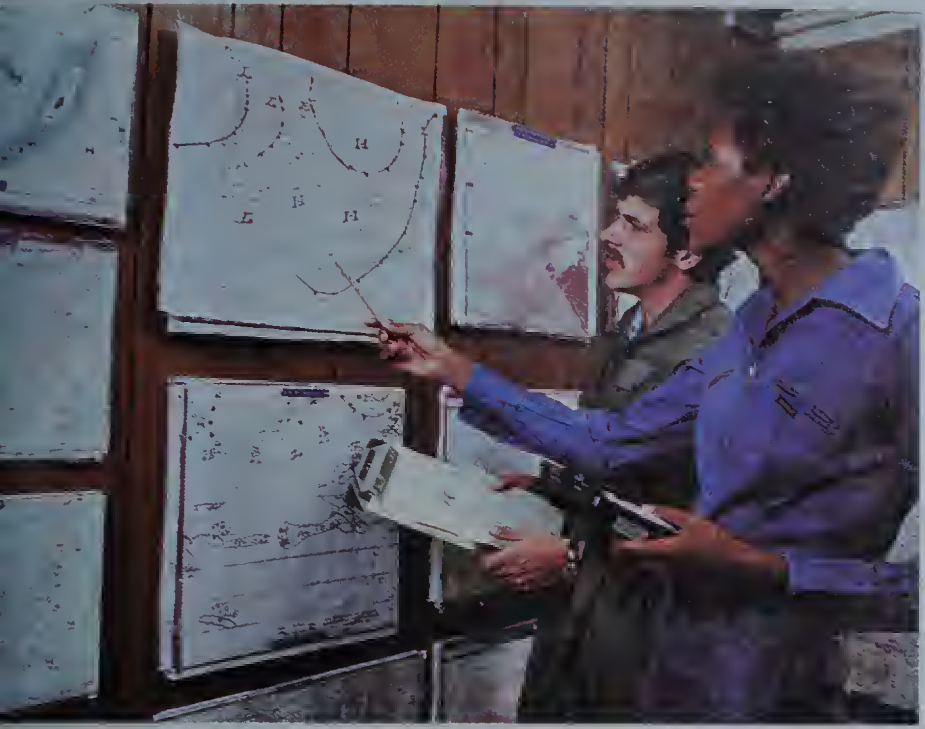
In summer, the land may be much warmer than the sea. Then air over the land is warmed. Cooler air from the sea settles under the warm air, forcing it to rise. This is called a "sea breeze." If the water is very cold, a sea breeze may be chilly, even on a sunny day.

Some parts of the earth are very cold in winter. The air above these areas becomes cold, too. Other parts are warm in winter, and they warm the air over them. These differences in temperature between huge masses of air are an important cause of the earth's winds. When the wind blows, it is often a result of air from a cool place pushing aside air at a warm place.

In summer, there usually are not such large temperature differences. Except for small, wild thunderstorms, winds are often lighter in summer than in winter.







JOBS Using Science

Most people are concerned about the wind direction and speed at some time. But a few people need to know what the wind is like every day. Their jobs depend on it.

The amount of fuel that a plane uses depends upon the wind direction and speed. A plane flying against the wind uses more fuel than a plane flying with the wind. This is an important fact for pilots to know about.

With what wind direction would a plane flying west use less fuel? With what wind direction do you think a plane flying west would make better time?

Some scientists work with wind tunnels. They put different things, such as model cars or planes, in a wind tunnel. Then a high-speed wind is produced in the tunnel. The scientists then can see how the models will react to different wind speeds. This helps them find out what design changes may be needed. This is very important when designing airplanes. Airplane companies want planes that will travel safely in strong winds and high air speeds.

Wind Speed LESSON 5

The speed of the wind, as well as its direction, affects many things. When there is almost no wind, it is hard to fly a kite. Sailboats do not move. Smog is not blown away.

When the wind is brisk, it is easy to fly a kite. Sailboats move fast. Smoke and smells are blown away. A brisk wind piles snow in drifts. But stronger winds can damage things. They can topple trees and collapse houses. They can cause huge waves that can smash boats and wash away beaches.

How many of your activities depend upon the wind speed? In what ways can a strong wind help you? In what ways can it hinder?

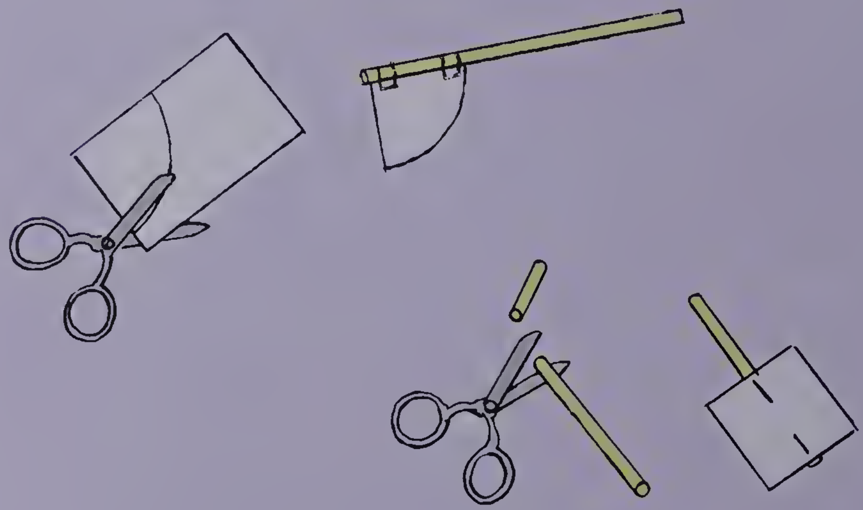
Measuring wind speed. There are many ways to measure the speed of the wind. You can let some fluffy seeds go and measure how far they drift before landing. You can watch how fast a pinwheel turns. But these are not very accurate ways to measure wind speed. Why?

SOMETHING TO TRY

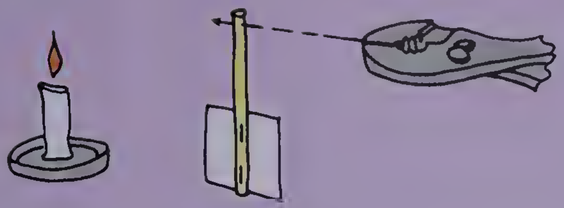
Here is a better way to measure wind speed.

Make an *anemometer*. This is the name of an instrument used to measure wind speed.

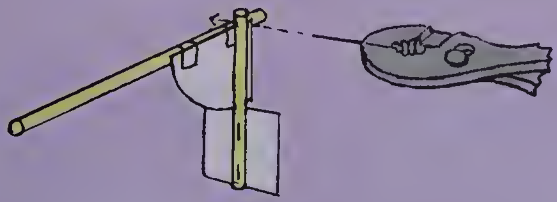
From a card, cut a quarter circle with a radius of 7 cm. Tape this near one end of a drinking straw as shown.



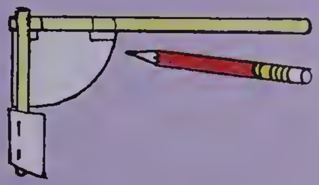
Next, cut a 15-cm piece from a second straw. At one end fasten a card about 7 cm on a side.



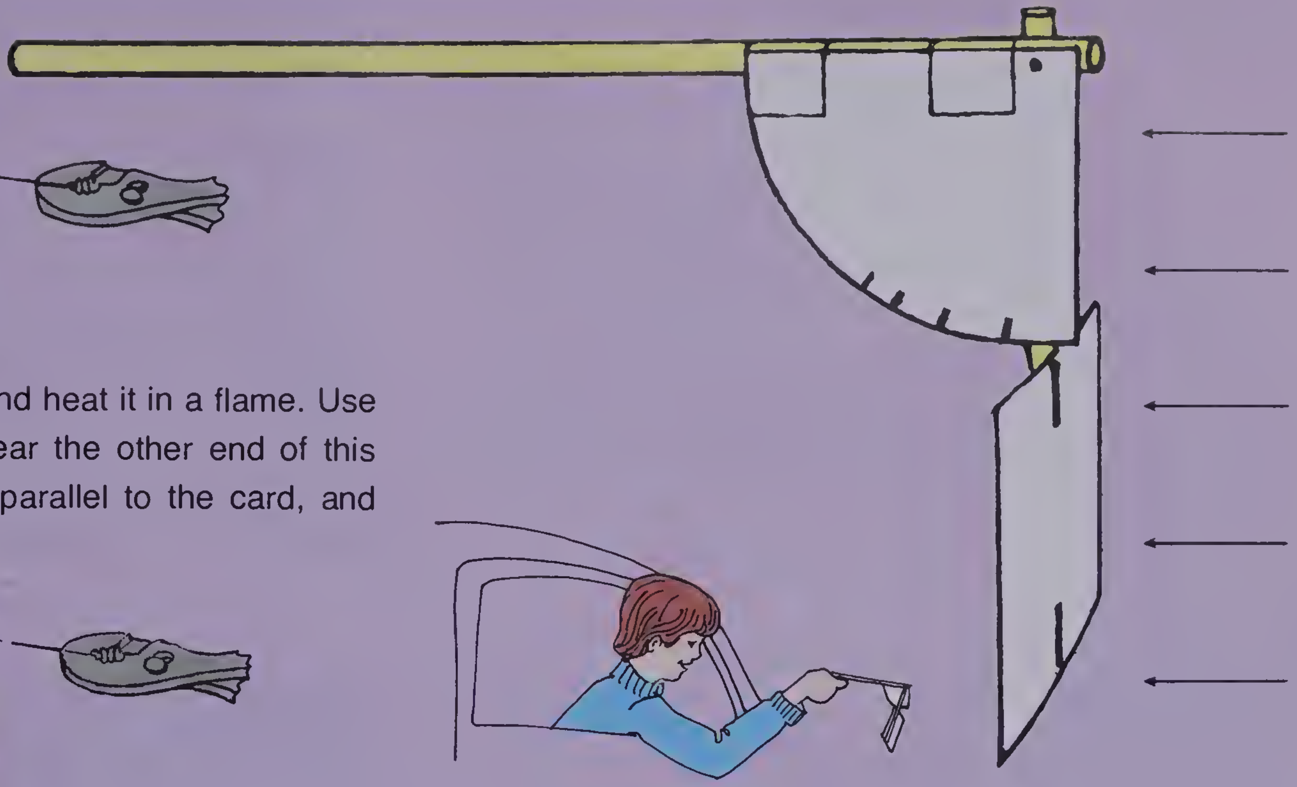
Then hold a pin with pliers and heat it in a flame. Use the hot pin to make a hole near the other end of this second straw. Make the hole parallel to the card, and slightly larger than the pin.



Push a clean pin through this hole, into the first straw. If the longer straw is held level, the second straw should hang straight down along the edge of the quarter circle.



When your anemometer is made, you will need to *calibrate* it. That means you will have to put wind speed marks in the proper places. You will need the help of someone at home who can drive. Ask them to take you in a car when it is calm outdoors.



When the car goes 10 kilometres per hour (km/h), hold your anemometer out the window. Hold it level. Make a mark where the slanted straw comes on the quarter circle. Label it "10." Do this for 15, 20, and 25 km/h.

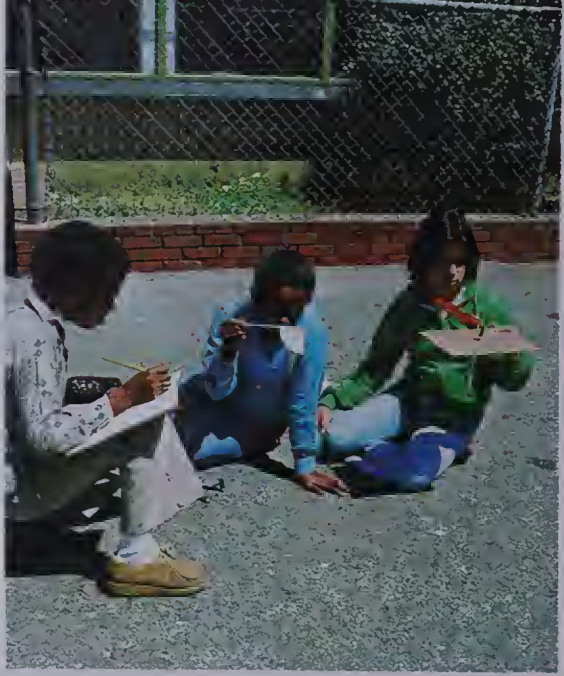
With a car, you probably cannot calibrate your scale for speeds less than about 10 km/h. So try this. Measure off 5.5 m. If you walk or run this distance in just 4 seconds, you will be going 5 km/h.

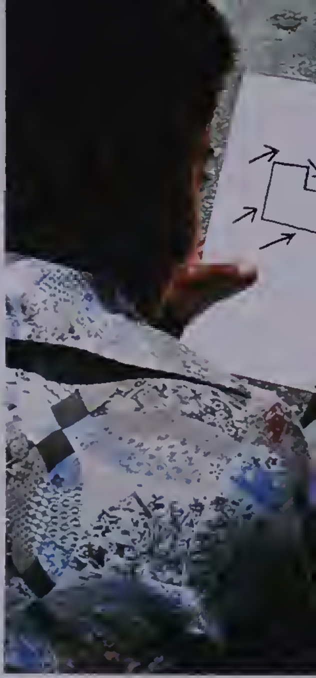
After you have marked 5, 10, 15, 20, and 25 km/h on your scale, you are ready to tell the wind speed. Hold your anemometer level. Watch where the pendulum comes. This is the wind speed in kilometres per hour.

SOMETHING TO TRY

Find out the wind direction and speed at several places around your school. First, make a scale drawing of your school. Next, pick out some places near the building where the wind direction and speed might be measured. Then take your wind vane and your anemometer to those places. Make the measurements and record them.

Does the wind blow in the same direction in all the places you checked? Does it blow at the same speed in each place? How does the speed compare at ground and at eye levels?





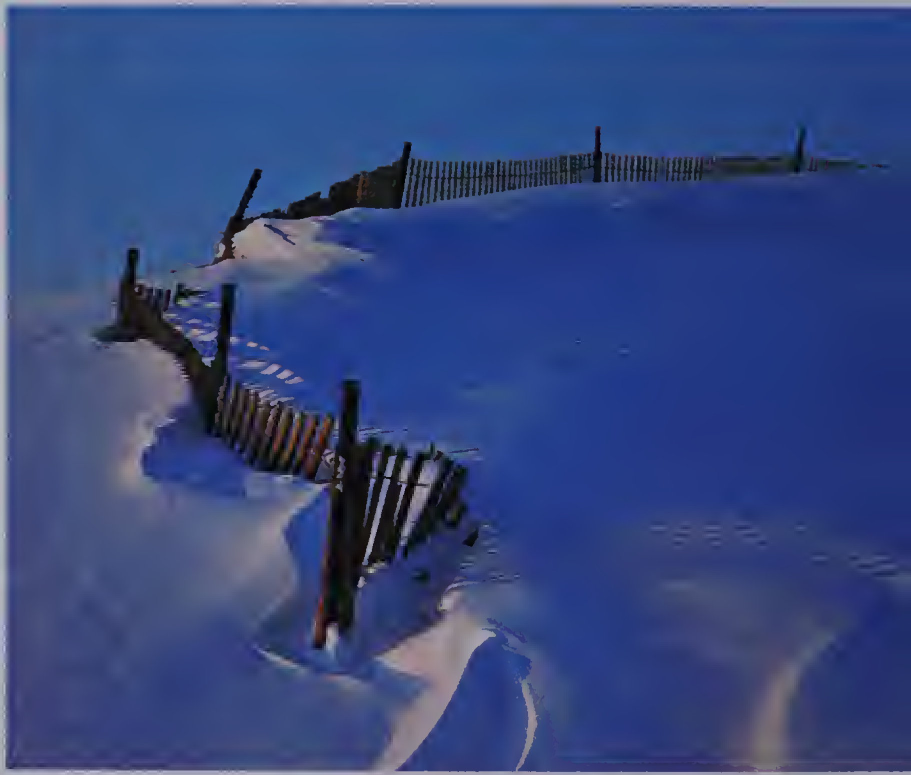
Investigating windbreaks. Sometimes fences are put up to make snow gather in one place instead of another. The snow piles up behind the fences, instead of on the highway.

In flat farmland, the wind often blows soil away. So rows of trees are planted as obstacles to the wind. This *windbreak* slows the wind and helps to hold the soil in place. If some soil is moved by the wind, it often settles behind the windbreak. It is not carried away from the farm.

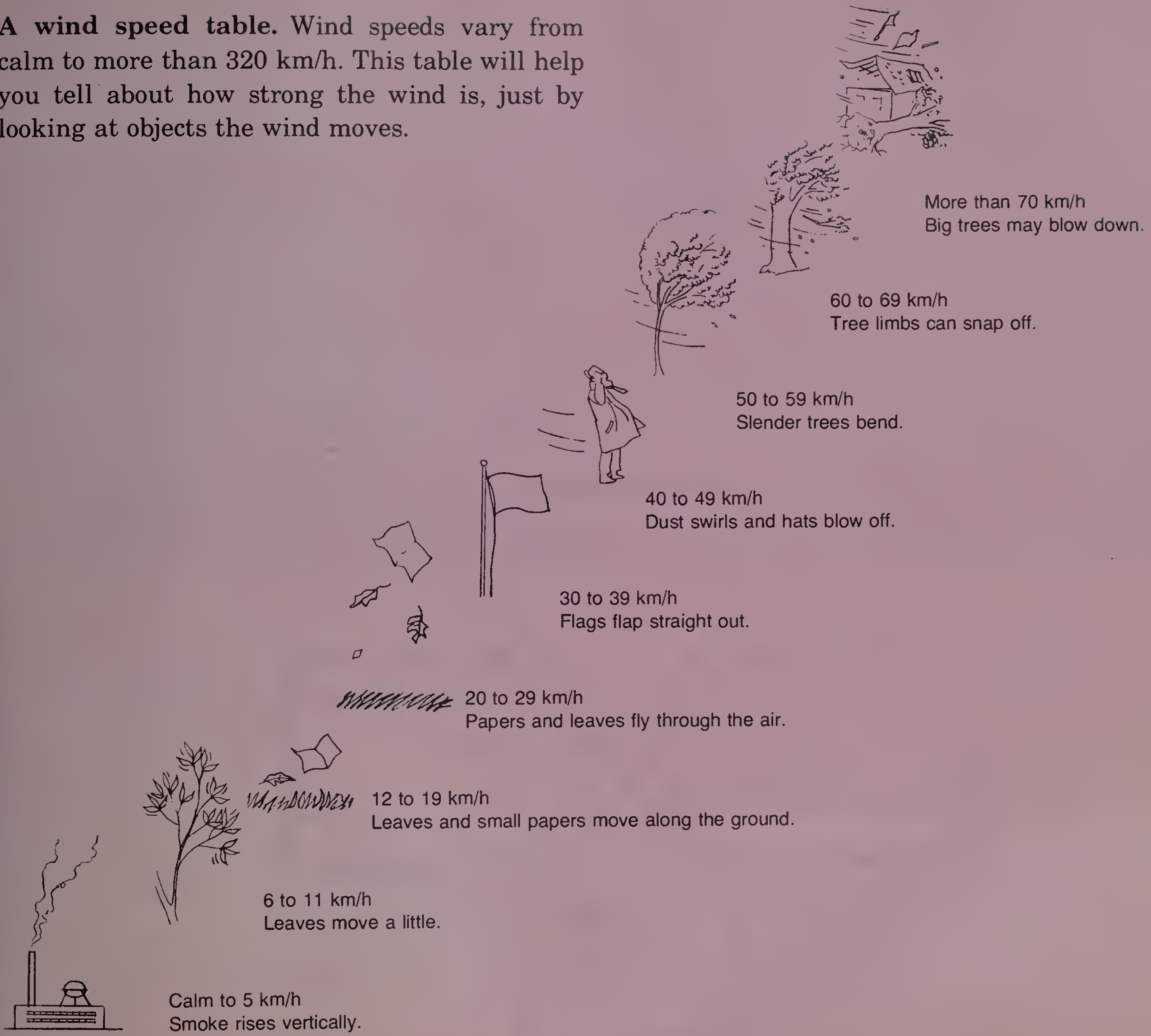
Look for places around home or school where

- wind-carried seeds gather in rows
- papers and leaves pile up
- wind-blown snow, sand, or soil settles

Try to figure out why these things collect where they do.



A wind speed table. Wind speeds vary from calm to more than 320 km/h. This table will help you tell about how strong the wind is, just by looking at objects the wind moves.



Calm to 5 km/h
Smoke rises vertically.

6 to 11 km/h
Leaves move a little.

12 to 19 km/h
Leaves and small papers move along the ground.

20 to 29 km/h
Papers and leaves fly through the air.

30 to 39 km/h
Flags flap straight out.

40 to 49 km/h
Dust swirls and hats blow off.

50 to 59 km/h
Slender trees bend.

60 to 69 km/h
Tree limbs can snap off.

More than 70 km/h
Big trees may blow down.

SOMETHING TO TRY

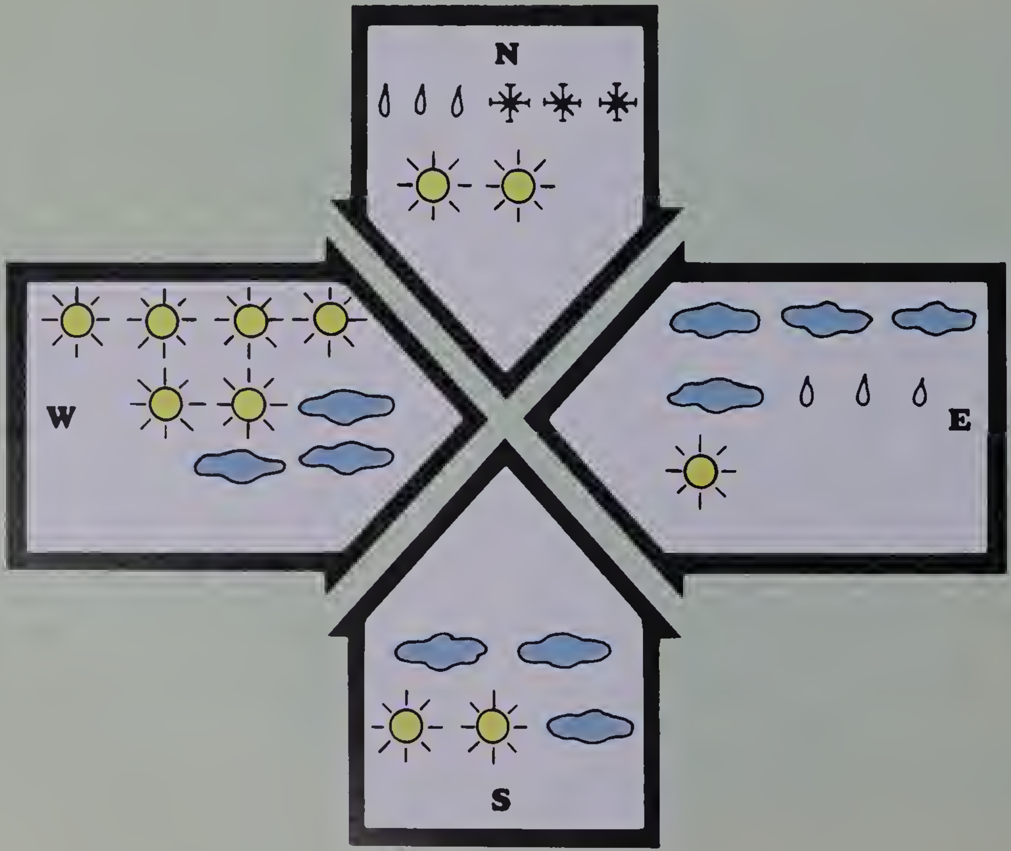
Find out what kind of weather tends to go with different wind directions where you live. First, draw four arrow-shaped boxes like those shown below. Label them with the compass directions—north, east, south, and west. In each box, record the weather that you see when the wind is from that direction. Make your observations twice a day. Use the symbols shown beside the chart. When you fill up one chart, make another.

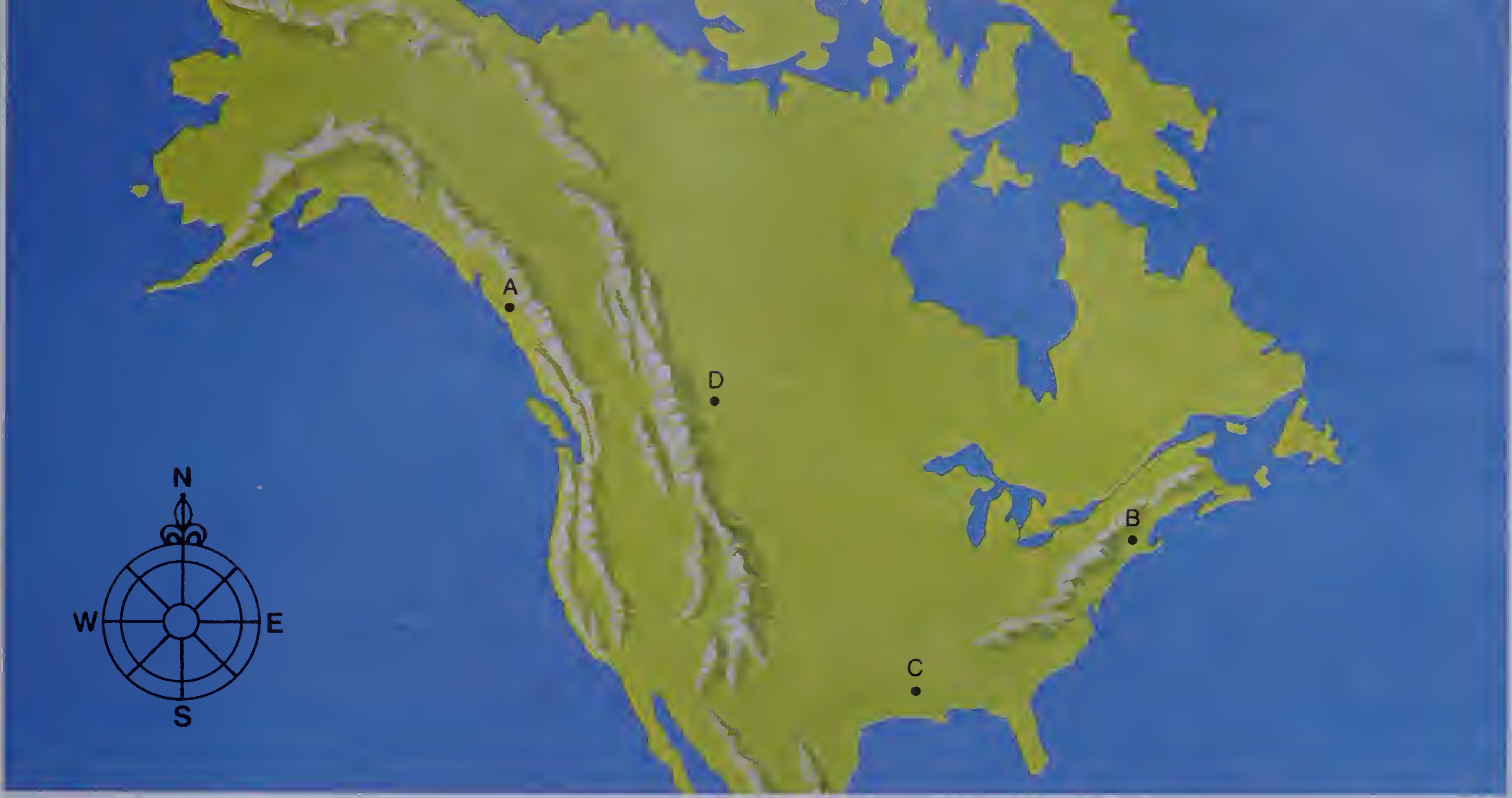
Keep a record for a month. At the end of that time, look at your record. What kind of weather happens most often when there is

- an east wind?
- a west wind?
- a north wind?
- a south wind?

With what wind direction does the weather change the least? With what wind direction does the weather change the most?

☀ Clear
☁ Cloudy
💧 Rain
❄ Snow





Weather, wind direction, and land forms. The kind of weather that goes with winds from different directions depends upon many things. At city A, for example, an ocean lies to the west. Mountains lie to the east. At "A" a west wind would bring air from a cool ocean surface. So the weather would be cool and damp. An east wind would bring air from dry land and down a mountain. So it would bring warm, dry weather.

Why might an east wind at "B" bring cool, damp weather? Why might a west wind bring drier weather?

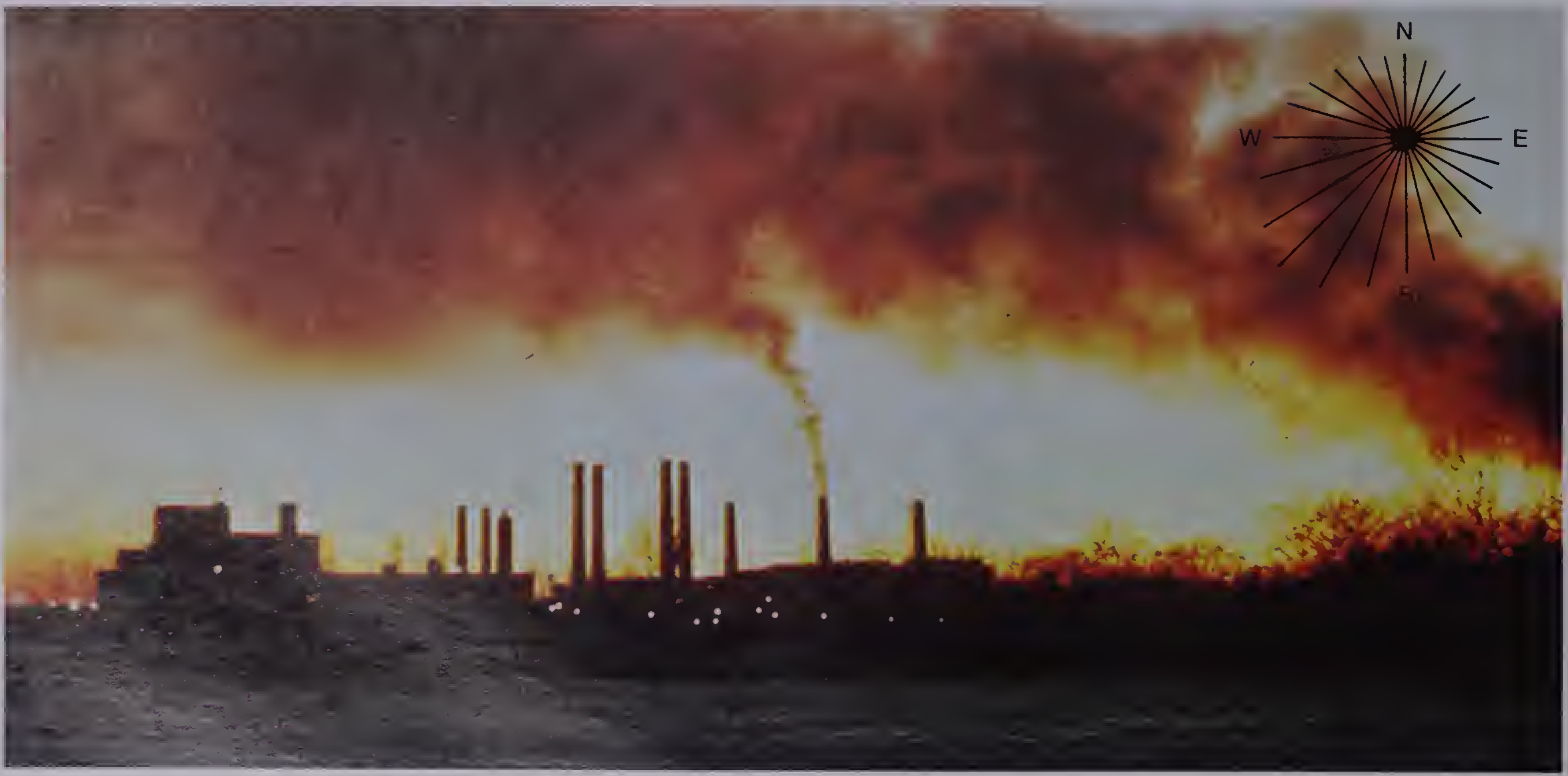
A west wind at "A" would bring moisture, perhaps rain, from the ocean. But by the time the air crossed the Rocky Mountains, it would have lost most of its moisture. When it got to "D," it would probably be dry. A city at "D" would have far different weather from a city at "A."

A warm sea lies just south of "C." So, with a south wind, "C" might have warm, damp air, with rain and maybe thunderstorms. But with a south wind, "D" might have only hot, dry weather. There is no warm sea near "D."

Wind and smog. Smog is smoke and fog. It is a weather condition caused mostly by people. But the wind can affect smog conditions in different parts of a city, too. The wind determines what direction the smoke and other pollution will go. Knowing the *average wind direction* helps to decide the best places to build homes.

Wind roses. Weather records sometimes show wind directions by means of a *wind rose*. A wind rose is made up of a dot and a set of lines. The lines show the direction and speed of the wind. The position of each line shows the direction of the wind on a certain day. The length of each line shows the speed. By watching all the lines, you can get an idea of the usual wind speed and direction.

The wind rose in the picture shows the wind pattern for a city. Suppose that this city has many factories producing smoke. In which section of the city would it probably be best to live? Where would it be best to locate the factories?

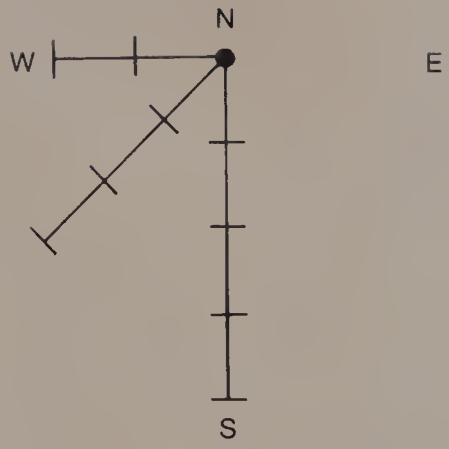


SOMETHING TO TRY

Make a wind rose for the place where you live. Use a dot to represent you. Above the dot is north; below, south; to the right, east; to the left, west.

Then, once each day for a week or more, measure the wind direction and speed. Record each observation. Show the direction of the wind as a line running toward the dot. Let the length of the line show the wind's speed. For example, each centimetre of line could stand for 5 km/h of wind.

If the wind is blowing at 20 km/h, your line should be 4 cm long. The picture shows just such a wind coming from the south. The wind rose also shows a 10 km/h wind from the west, and a 15 km/h wind from the southwest.



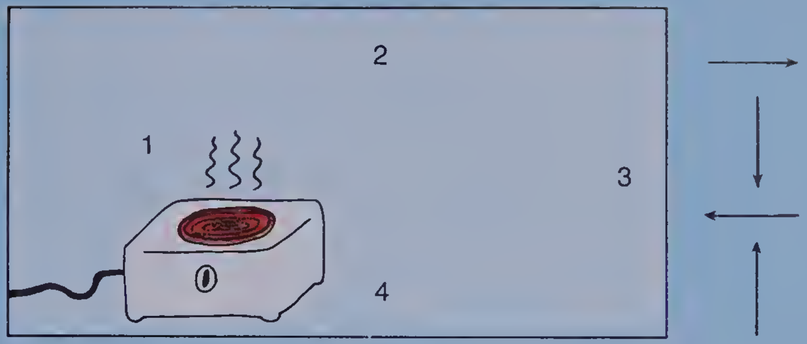
Chill factor. In cold weather, the person who gives the weather reports on TV often tells about the *chill factor*. When there is a strong wind, it feels colder than it really is. This is what the chill factor means. On a calm day when the thermometer reads 0°C (or freezing), it might seem pleasant to you. But in a strong wind, 0°C might feel very cold. So wind not only affects the weather, but it also affects how a person feels.

Ideas for REVIEW

- Cold fluids tend to be heavier, or more dense, than warm ones.
- Warm, less dense fluids tend to be pushed up by cold fluids.
- A cold fluid pushing a warmer, less dense fluid away is called convection.
- When temperature differences are great, convection takes place rapidly.
- A warm fluid over a cold fluid is stable.
- A cold fluid over a warm fluid is unstable.
- Winds are caused by cooler air pushing warmer air out of the way. This turning over of air masses causes winds to blow and clouds to form.
- A wind vane shows the direction from which the wind comes.
- An anemometer measures wind speed.
- A wind rose is a way to show wind direction and speed over a period of time.
- Often, the wind direction helps to determine the weather at a particular place.

TEST Your Understanding

A. The numbers in this drawing show four different places in a room. The hot plate is the only heat source. The arrows next to the drawing show four ways the air can move. On your paper, write the numbers 1 to 4. Then draw the arrow that shows how the air is moving at each number in the drawing. *Do not write in this book.*



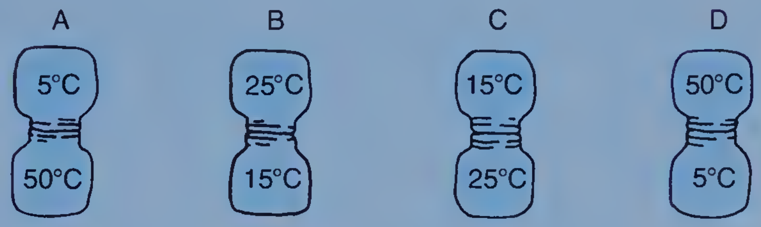
B. Each of these drawings shows a pair of water-filled jars. On your paper, write the numbers 5 to 8. Then next to those numbers, write the letter of the jars that best matches the words below.

5. very stable

6. very unstable

7. a little stable

8. a little unstable



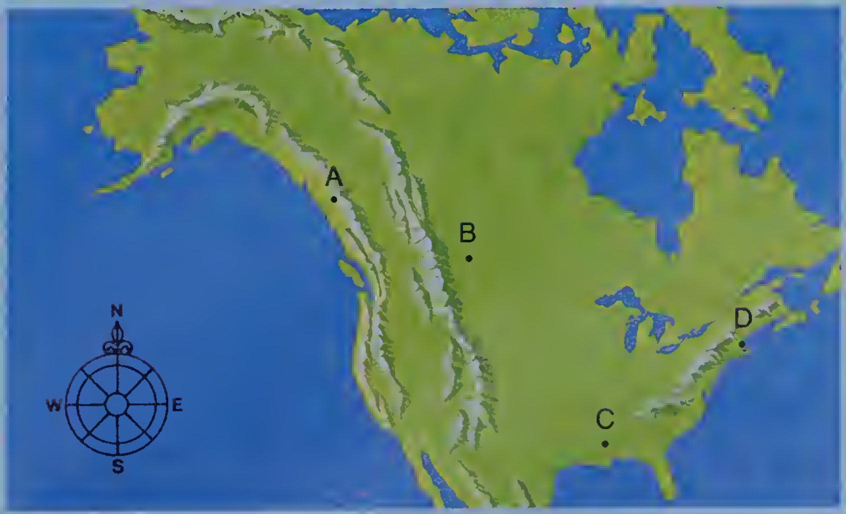
C. Look at this map. Then write the answers to each of the following questions on your paper.

9. What kind of weather would a west wind bring to city A?

10. What kind of weather would a west wind bring to city D?

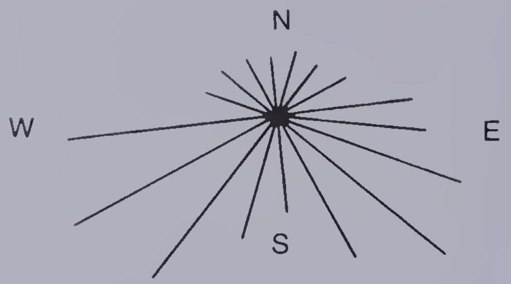
11. What kind of weather would a south wind bring to city C?

12. What kind of weather would an east wind bring to city B?



PROBLEMS

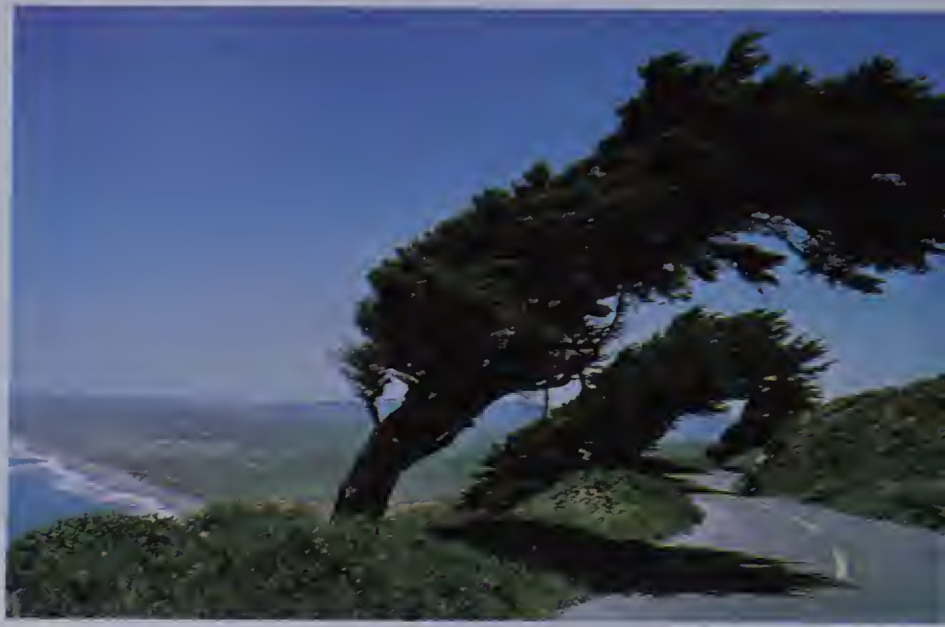
1. The wind rose for a certain city looks like this.



If you consider
- smoke
- noise
- smells

where would be the best places to build or locate
- a house?
- an airport?
- a park?
- a clean, but noisy factory?
- a smoky, but quiet factory?
- a dump?

Explain your answers.

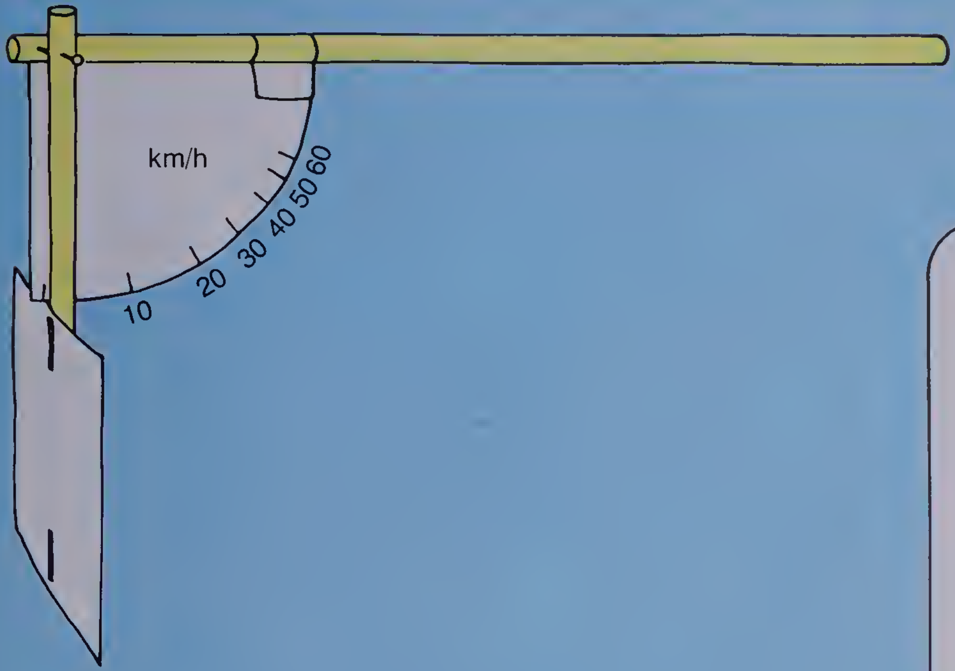


2. Some living things are affected more than others by the wind. How do you think this tree was affected by the wind?

What problems do you think a windy day would cause flying insects? Where do you think they go when it is windy?

How do you think this might affect bats, since bats eat mostly flying insects?

3. This wind scale was calibrated carefully. The numbers for the wind speed are not evenly spaced. Why do you think this happened?



4. Imagine you are swimming at this ocean shore on a hot summer day. How do you think the air would move at ground level? How would it move 100 m above the ground?

FIND OUT on Your Own

1. Can you think of a way to make your anemometer into a wind vane, too? How would you do it? Remember

- to counterbalance it with some clay
- the easier it turns, the better wind vane it makes

2. Find out how the *climate* (weather for a long time) for one city compares with that for another. You will be able to do this by using an atlas. Choose a few cities that interest you. Then look at what might cause the differences in their climates. Compare

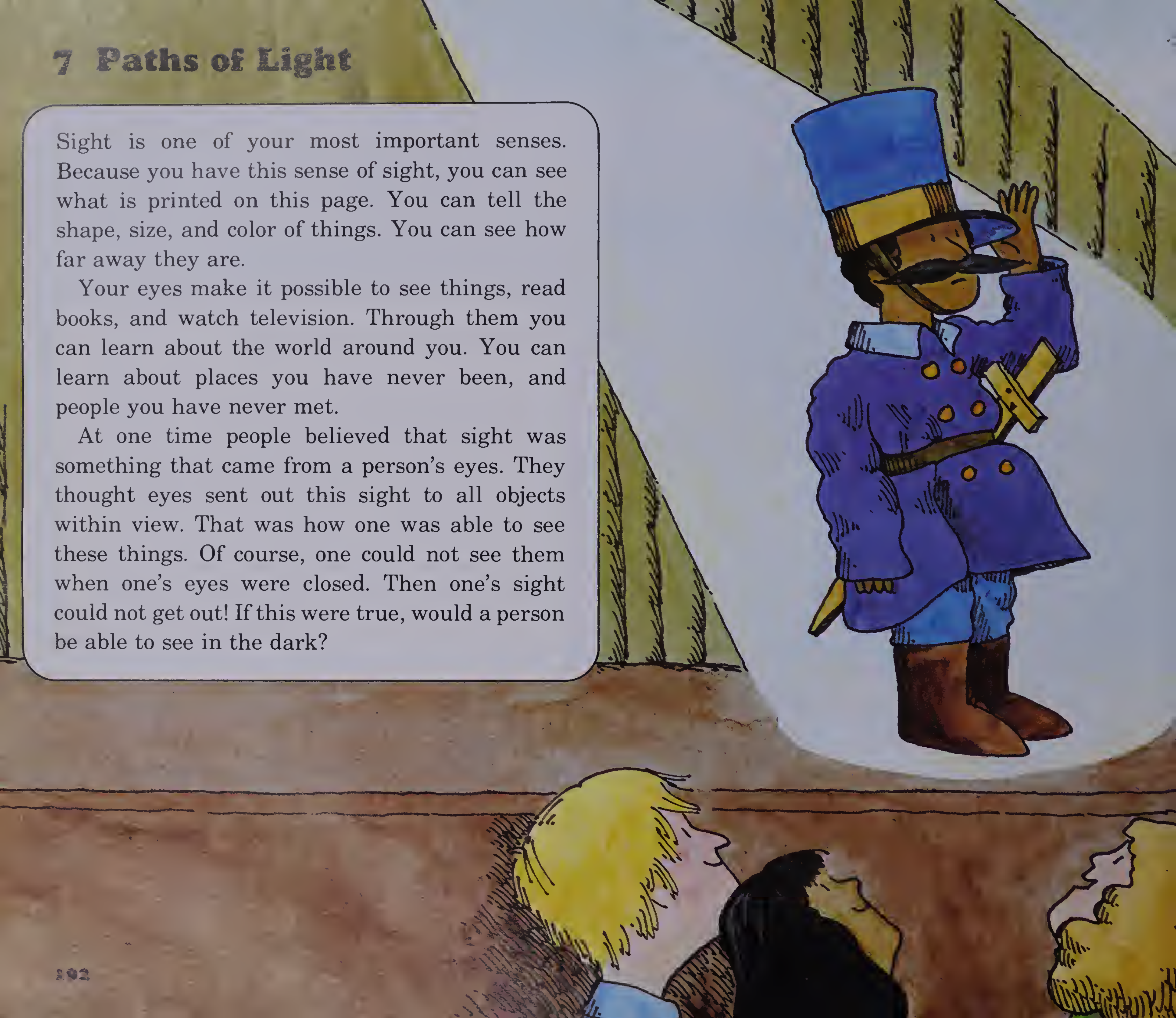
- how far north or south the cities are
- nearness to an ocean or large lake
- the usual wind direction for these cities
- nearness and direction to mountains

7 Paths of Light

Sight is one of your most important senses. Because you have this sense of sight, you can see what is printed on this page. You can tell the shape, size, and color of things. You can see how far away they are.

Your eyes make it possible to see things, read books, and watch television. Through them you can learn about the world around you. You can learn about places you have never been, and people you have never met.

At one time people believed that sight was something that came from a person's eyes. They thought eyes sent out this sight to all objects within view. That was how one was able to see these things. Of course, one could not see them when one's eyes were closed. Then one's sight could not get out! If this were true, would a person be able to see in the dark?



Light and How It Acts LESSON 1

Today we know that we see because light comes into our eyes. It is not because something called "sight" goes out from them. When our eyes are closed, why can't we see things? We cannot see because light cannot get in, not because "sight" cannot get out!

Where does the light come from that we see by? How does it act?

Producers of light. Candle flames, electric lights, and fireflies are alike in one way. They all produce light. The sun also produces light. So do the stars we see at night. All these are known as *sources* of light.

The light from these sources goes off in all directions. We may think of each of these directions as a path of light. And we speak of light that takes the same path, or nearly the same path, as a *light beam.* Sun shining through spaces in clouds often appears as beams of sunlight. Do these beams look straight or crooked?

Reflectors of light. Many things do not produce their own light. Does this book, for example, produce light? Does your desk, or the walls of your classroom? None of these glow like the sun or a light bulb. Yet you can see them easily in a lighted room. How is it that you can see these things?

You can see them because they *reflect* some light that comes to them from other sources. All these things receive light from other sources such as the sun or electric lights. They also may receive light reflected from nearby objects.

SOMETHING TO THINK ABOUT

Can something produce light and reflect it at the same time? A match produces light. Does it also reflect light?

SOME THINGS TO TRY

You can learn more about light and sight by making and observing a dark box.

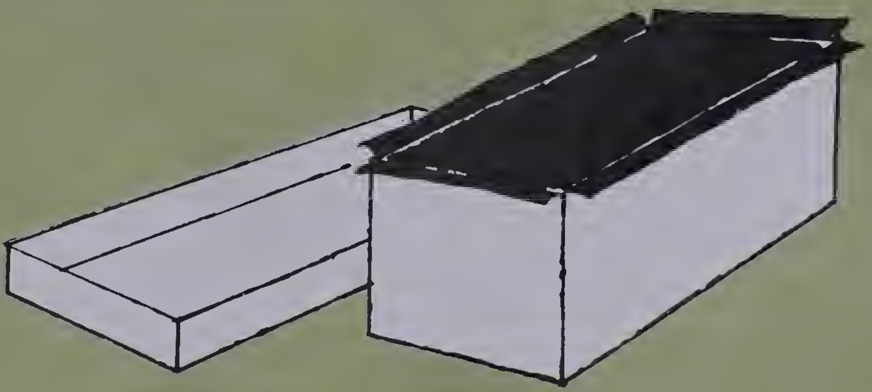
Find a shoe box with a tight-fitting lid. Line the inside of the box and lid with black paper.

With the help of your dark box you can find the answer to the following questions:

1. Can you trap light inside a container?

On a sunny day fill your box with sunlight and close the cover tightly. Quickly take the box to a very dark place, such as a closet. Open the box in the dark place. Does any light come out?

Try this a few times, and watch very closely. From your observations, would you say that light seems to act like matter? Does it seem to act like sand, water, or air? Could you trap these things in your box?



2. What do you need in order to see things?

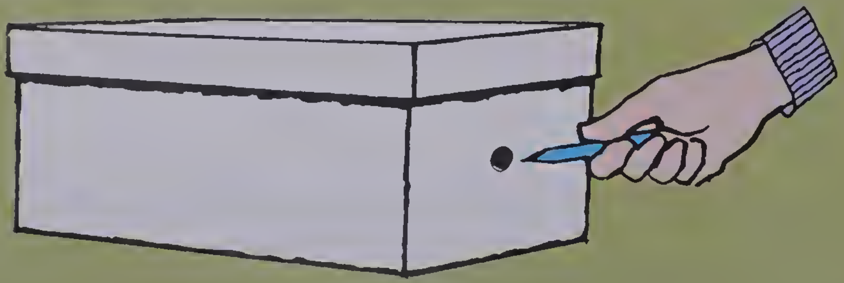
With a sharp pencil, poke a peephole in one end of your dark box. Hold one eye close to the peephole and look in. Can you see the inside of the box? Can you see objects such as a pencil or shiny paper clip placed inside the box?

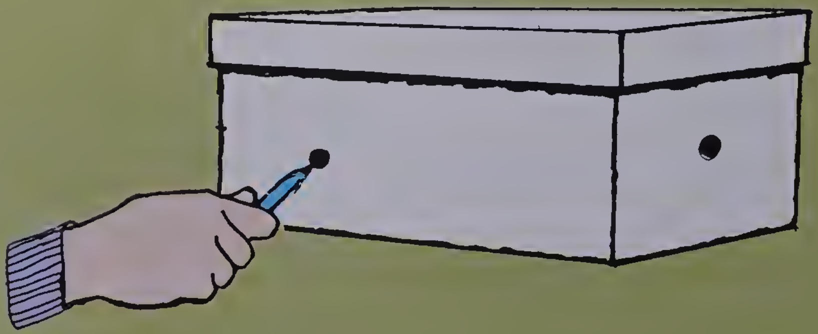
Now poke a second hole in the side of the box, around the corner from the first hole. Do this about 5 cm from the other end. Suppose you let the bright sun shine in this second hole while you peek through the first hole. Will you see sunlight inside the box? Make a prediction. Then test your prediction.

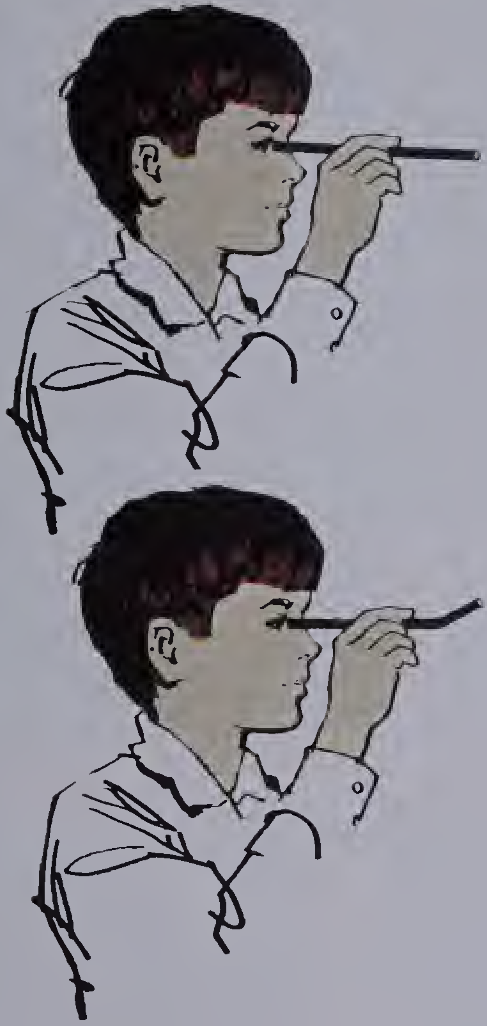
Now suppose you put some shiny foil and white paper in the box. Put them near the hole where the sunlight enters. Then what will you see through the peephole? Make a prediction. Test it.

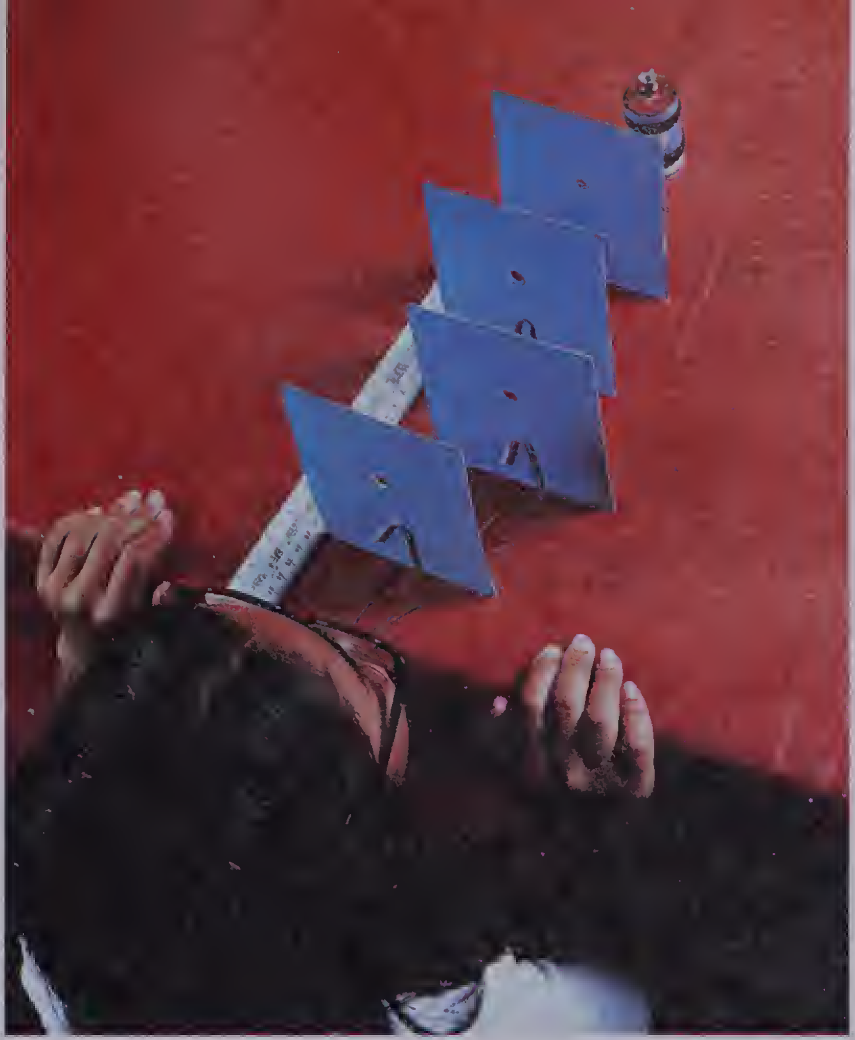
Blow some chalk dust into the box and quickly close it. Then let sunshine in the side hole and look through. Do you see a beam of light? Is it straight or curved?

Move the box around in the sunlight. Hold it in different positions—sideways and at a slant. Does the light beam inside the box move as you move the box? If so, what causes this to happen?









Finding out how light travels. This boy made a tube out of black paper about the size of a drinking straw. Then he looked through the tube. Could he see an object such as a book?

Next he bent the tube and looked at the same object. Did he see the same thing as before? What did he find out about the path of light through his straight tube and bent tube?

This girl is trying to see the lighted bulb through the holes in the cards. Each hole is just about the same size as the bulb itself. The holes are all the same distance as the bulb is from the table top.

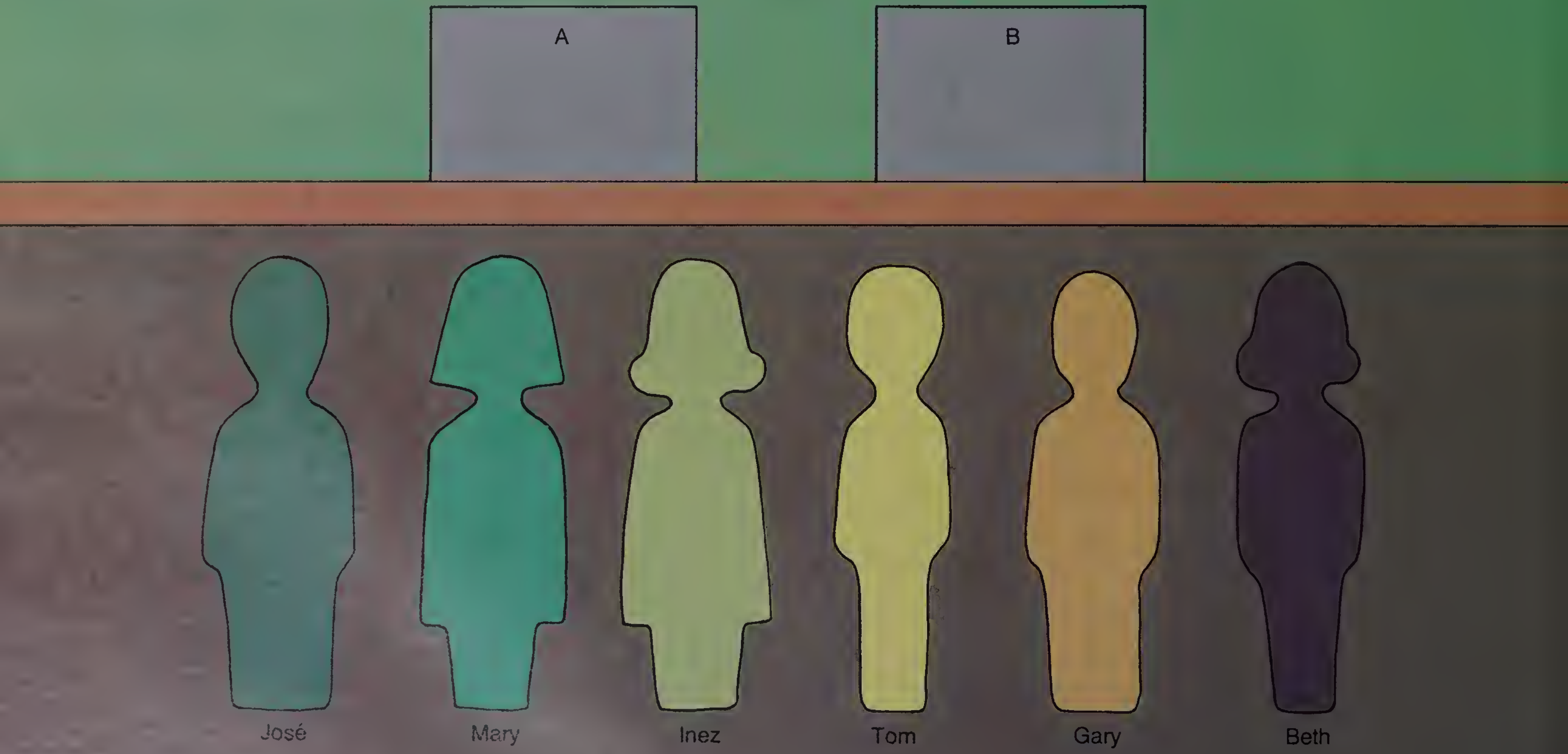
What must the girl do in order to see the light? Is there more than one way she can move the cards to see the light?

Reflection by Flat Mirrors LESSON 2

One class decided to find out some things about mirrors. Here's what they did. Six students sat in a row. Their chairs were about 3 m from the chalkboard. Two mirrors were standing in the chalk tray. Each person looked at one mirror, and then the other mirror. Each student noted whose face could be seen in each mirror. Whom do you suppose each person saw?

Which classmate did José see when he looked at mirror A? At mirror B? To help you predict, imagine the path of light between José and the mirror.

Could Beth see Mary in either mirror? Could Mary see herself? Predict which classmates each pupil would see. You might test your predictions by trying this with some classmates.

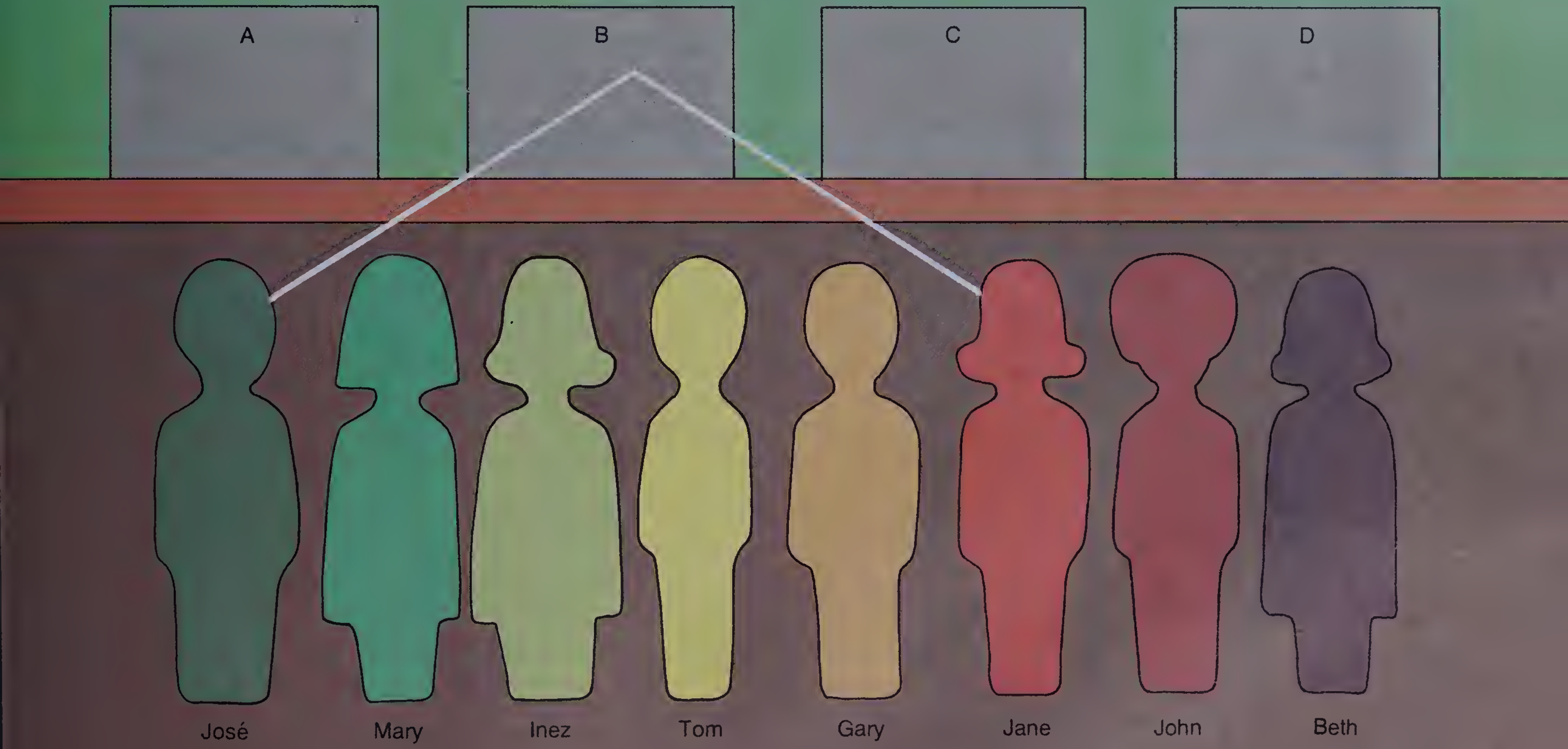


The same class placed two more mirrors on the tray and used strings to show light paths. Three more students joined the group. Again, each person noted whose face could be seen.

Since Inez could see Beth in mirror C, light must go from Beth to Inez. Since José could see Jane in mirror B, light must go from Jane to José. And it must go by way of the mirror.

To show this, José held one end of a string which he taped to mirror B. The other half of the string went from mirror B to Jane. The string showed the path of light from Jane to José.

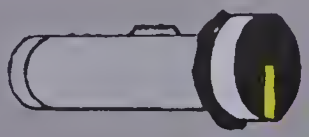
José taped other strings to each of the other mirrors and to the person he saw in the mirror. Do you think these classmates saw José, too? Try this and see.



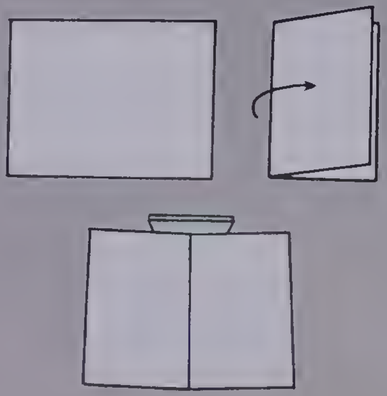
SOMETHING TO TRY

Compare the path of light before it hits a mirror with the path after it hits. How is it the same? How is it different?

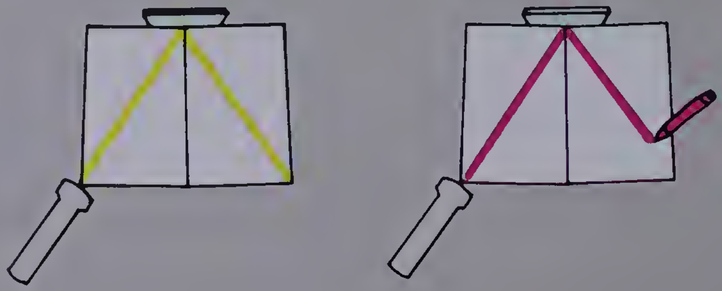
To find out you will need a mirror, paper, crayons, scissors, and a flashlight. Tape black paper over the end of the flashlight. Cut a slit from the center to the edge of this paper. When the light shines through the slit onto the paper, it will make a narrow path.



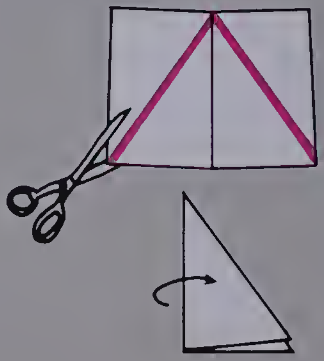
Next, fold a sheet of paper in half. Open it out flat. Lay it in front of an upright mirror. The edge should be even with the mirror. And the fold should be in line with the center of the mirror. A small mirror will stand upright if you tape it to a book or block of wood.



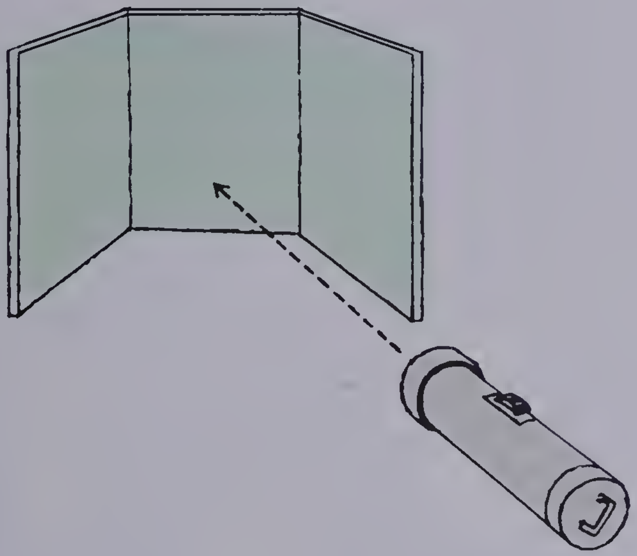
Shine a beam of light across the surface of the paper. Aim it where the fold and mirror meet. Can you see a second path of light leaving the mirror? Using a crayon or pencil, trace both paths. Then cut the paper along the paths you have drawn. What is the shape of the cut-out paper? Fold the cut-out piece along the same fold line. Do the pieces on both sides of the fold match?



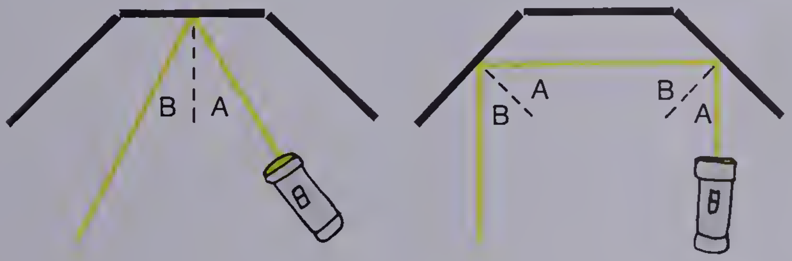
Do this again several times. Put a new piece of folded paper in position next to the mirror each time. And hold the flashlight in a different position. But be sure the light is always hitting the mirror at the fold line. Are the angles on each side of the fold always the same?

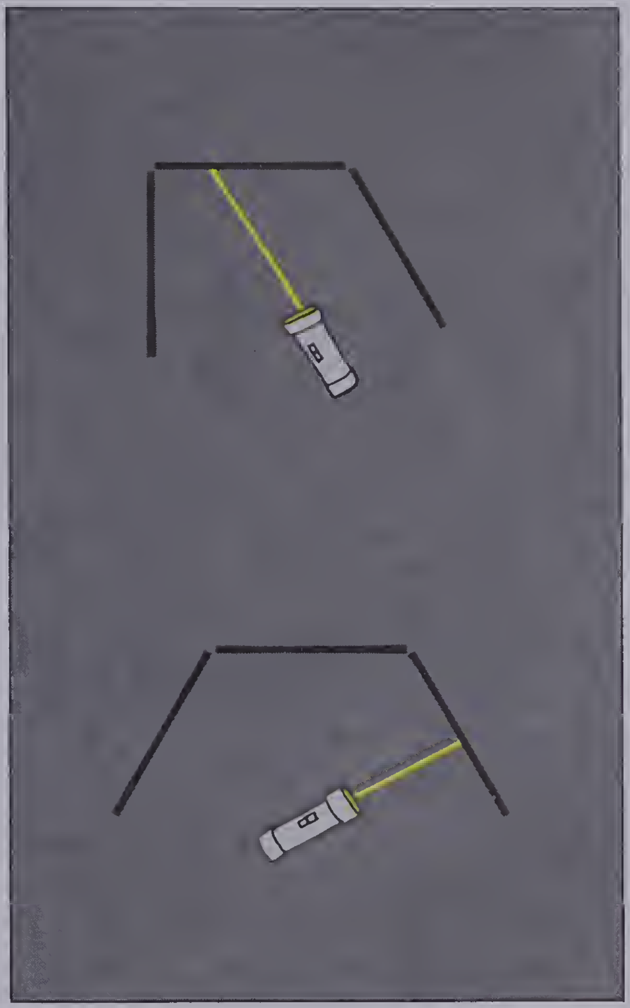


Predicting the paths of reflected light. To study reflected light, Jean used a flashlight and three mirrors taped together. First she predicted the path the reflected light would take.



Then she tested her prediction. She tried this several times. Each time she held the flashlight in a different position. She placed a paper with a fold mark against each mirror. By knowing the angle at "A," she could predict the angle at "B." How could she do this?

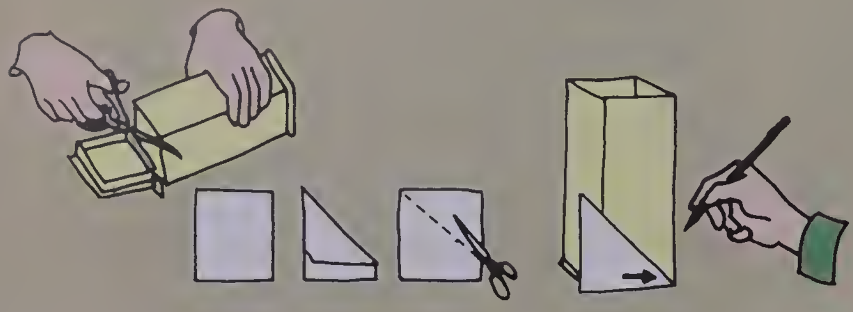




SOMETHING TO THINK ABOUT AND TRY

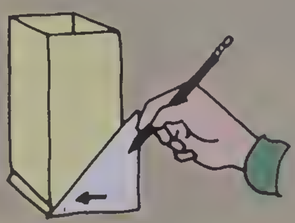
Here are two more tests that Jean made. Try to predict the path of reflected light in each. Then set up three mirrors and test your predictions.

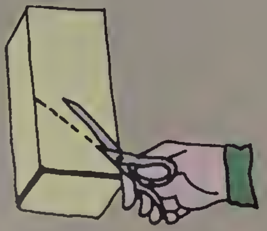
A periscope uses reflected light. It helps people see objects that are not in their line of sight. Can you think of a time when you might want a periscope?



To make your own periscope cut off the tops of two milk cartons. Make an "angle marker" by folding and cutting a piece of paper like this one. Place your angle marker along the bottom of one carton as shown. Make sure that your "angle marker" points to the right-hand corner. Draw a line.

On the opposite side of the milk carton do the same thing. Be sure the angle marker points to the left-hand corner as you draw a line.



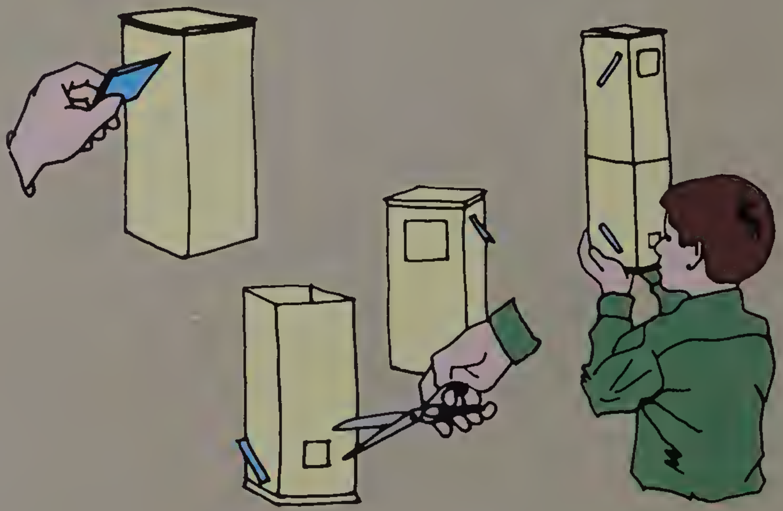


Do the same things to the other milk carton. Now with a pair of scissors, make a slit along all four lines.

Slide one mirror into one carton so that it fits between the two slits. Do the same with the other mirror and the other carton. Make sure that the shiny sides of the mirrors face up.

Make a hole in one side of each carton. Cut the hole so that it is opposite to the mirror.

Now place the open end of one carton over the open end of the other. This can be done in several ways.



How would you put your periscope together to do each of the following?

- see objects in front of you
- look at things on your right
- see behind you

Does anything you see surprise you?

Make a drawing that shows how the light bounces off the mirrors of your periscope.

Images in mirrors. Have you ever been fooled by a mirror? Did you ever think that what you saw in a mirror was real? The "mirror world" looks much like the real world.

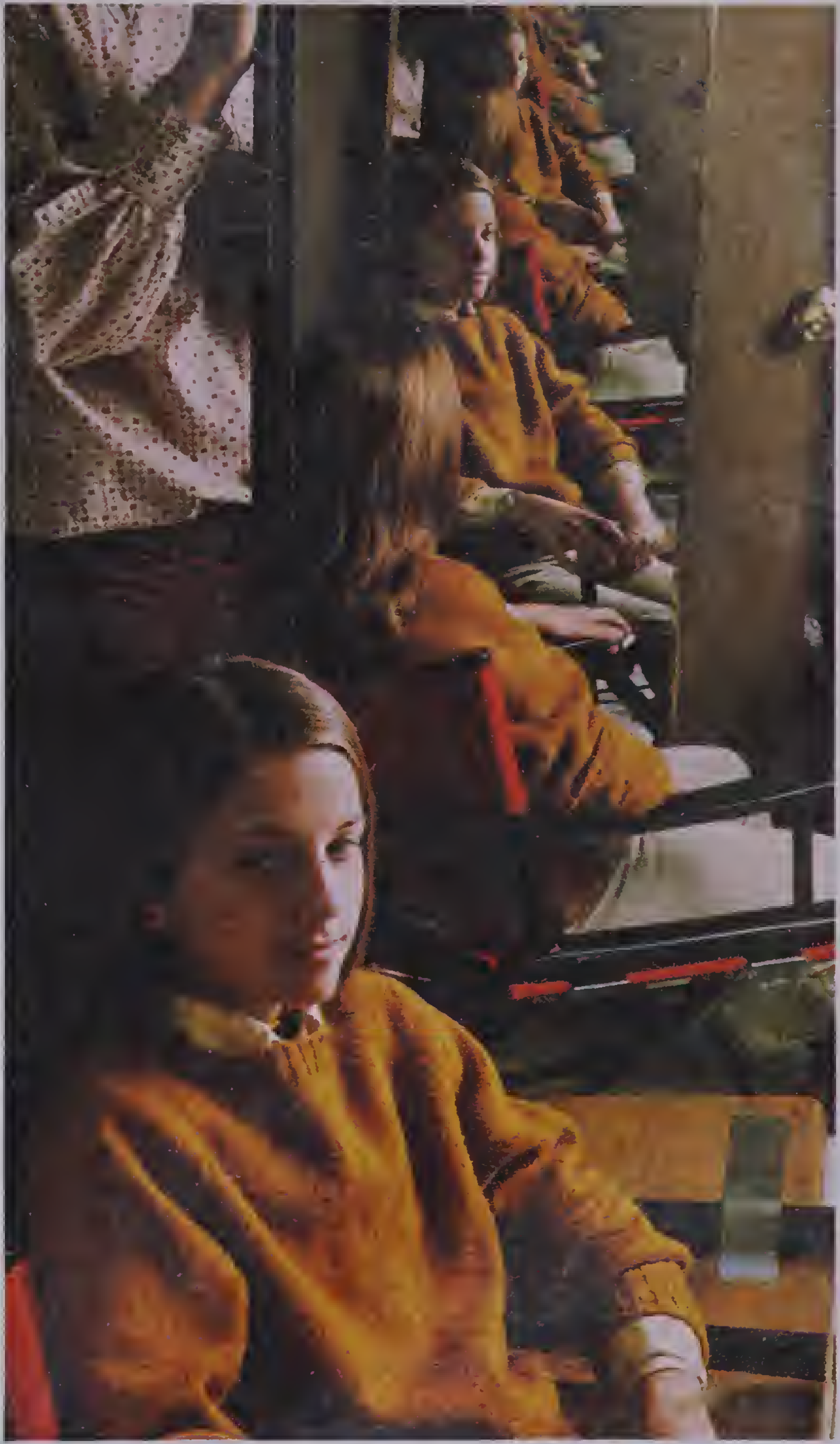
When you look at a mirror you do not see the real thing. What you see is a reflection, or *image.* If the light is right, this image looks real. Sometimes it is hard to tell a mirror image from the real object.

Images in a flat mirror seem to be somewhere behind the glass. But if you reach for them you bump into the glass.

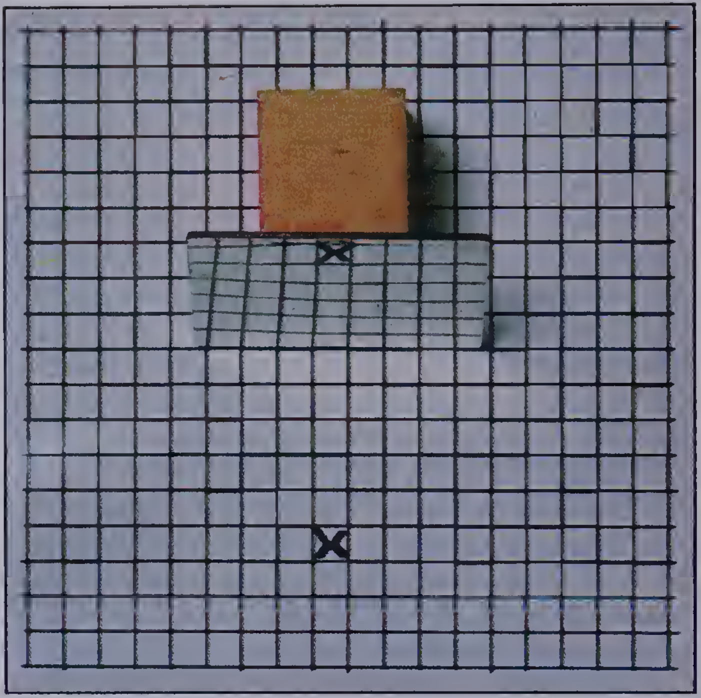
Sometime you may have walked into a room that looked much larger than it really was. Then you discovered that all of one wall was covered by a mirror. Mirrors often are used for this purpose in restaurants, barber shops, and private homes.

Are the mirrors in the picture playing a trick on you? How many images do you see? If the picture were longer, would you see more images than this? How many more?

How many mirrors are there in the picture? How are they set up?



How near . . . how far? The next time you are standing in front of a mirror, move very close to it. Note where your image appears. Now move farther away. Again watch your image. Do this several times. Try to predict where your image will appear each time you move.



SOMETHING TO TRY

When you change an object's place in front of a mirror, what happens to its image?

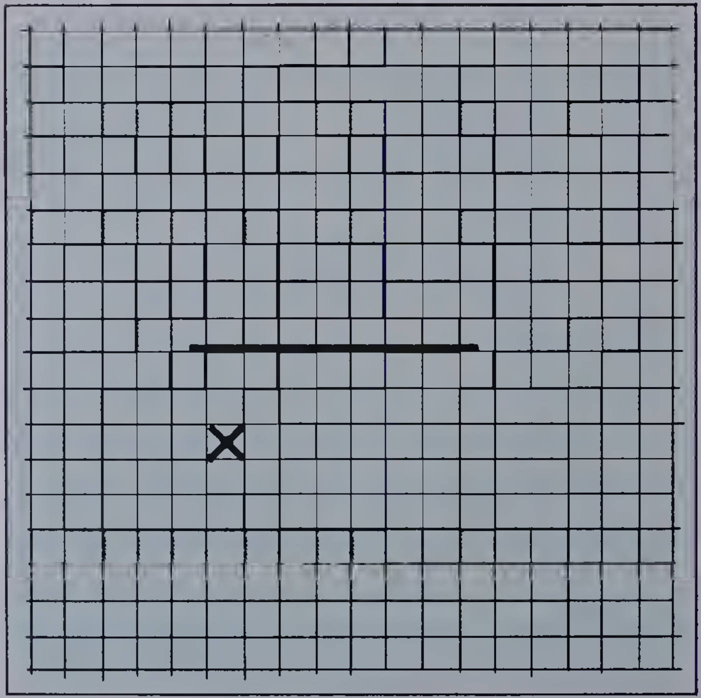
Tape a small flat mirror to one side of a block of wood. Then stand this on a piece of graph paper. Now make a mark about six squares in front of the mirror. Look into the mirror.

How far behind the mirror does the image of the mark seem to be? Do this again. Record the places of both the mark and the image.

Now use another piece of graph paper without the mirror, as shown at the right. Make a mark in a different square. Can you predict where the image will appear in the mirror? Put an "X" where you think it will appear. This is a record of your prediction. Now test your prediction using the mirror.

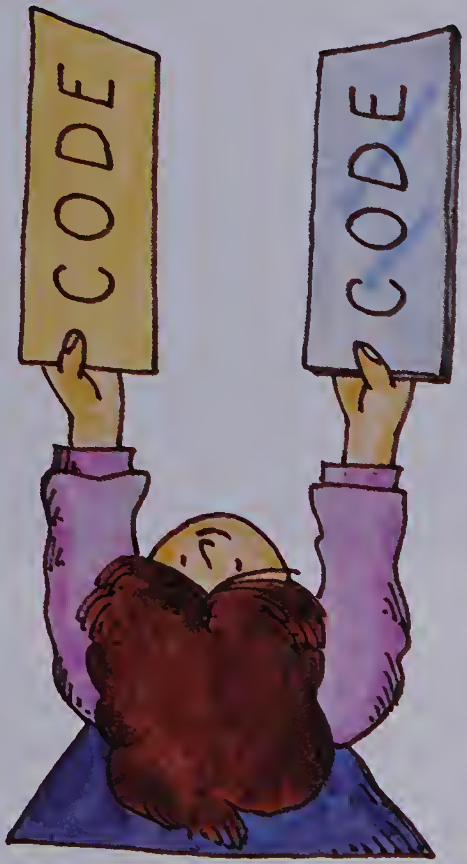
Try this several more times. Choose a different square for the mark each time.

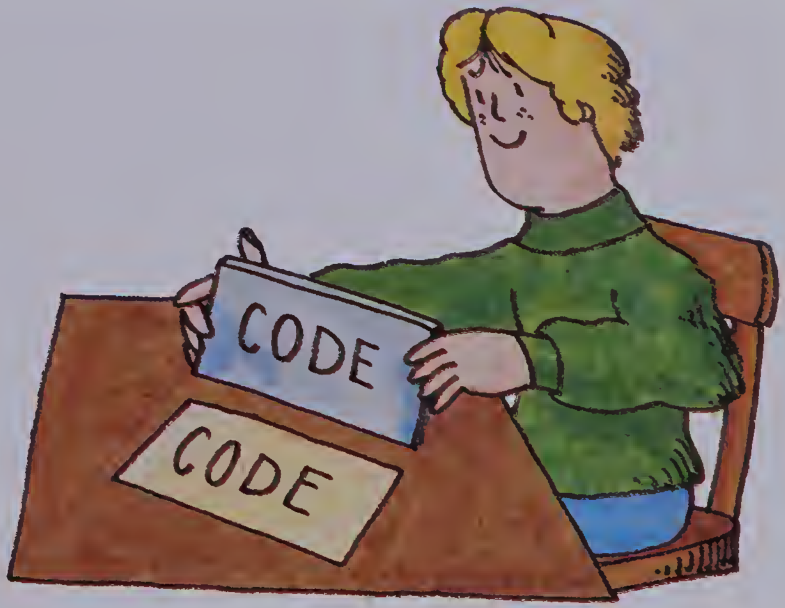
How does the image appear to move if the mark is moved to the right? If the mark is moved to the left? If the mark is moved closer to the mirror? If the mark is moved farther from the mirror?



Right side . . . left side. Is your image in a mirror just like you? When you wink your right eye does your image wink its right eye? Or does it wink its left eye?

What about the image of this page in a mirror? Does it look just like the page? Is it upside down, or switched from left to right? Would you be able to read this printing in a mirror?





SOMETHING TO TRY

Find out more about images in flat mirrors. Does the girl in the picture see the same thing as the boy? Each is holding a card with the same printed word—"CODE." But the card and mirror are held differently. Will this change the mirror image that each of them sees? If so, how will the image change?

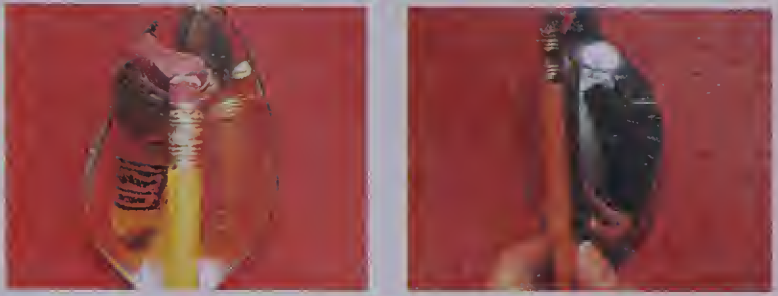
Reflection by Curved Mirrors LESSON 3

Have you ever noticed your reflection in shiny objects? Things like Christmas tree ornaments or shiny pots sometimes give very clear images. But many of these things have curved surfaces. And the image you see may be different! It can be large or small, right side up or upside down. The kind and amount of curve changes the image.

Curved surfaces. Some surfaces curve in, like the top side of a spoon. Surfaces shaped like this are called *concave*. Other surfaces curve out, like the bottom side of a spoon. These are called *convex* surfaces. Try to find some examples of each of these kinds of surfaces in your classroom and in your home.

The glass on your television screen curves outward. Is it concave or convex? The reflector behind a flashlight bulb is also curved. Is this curve concave or convex?

Look for convex and concave surfaces that reflect light. What sort of image do you see in each of the surfaces?



SOMETHING TO TRY

What do the images in a shiny spoon look like? Look at the concave side of a spoon, held about 30 cm away. Can you see your face in it? Is it right side up or upside down? Is it larger or smaller than it would be in a flat mirror held the same distance? Check to find out!

Before you turn the spoon over, predict what your image will look like in the convex side. Will it be right side up or upside down? Will you look fatter or thinner? Test your predictions!

Now hold a pencil close to the concave surface of the spoon. Look at the image of the pencil and your own image behind the pencil. Are both images right side up? Or upside down? Can you explain what you see? Now slowly move the pencil away from the spoon. Keep watching the image closely. When does the image change? In what way does it change?

Will this also happen on the convex surface of the spoon? Make a prediction. Then test your prediction.

SOMETHING ELSE TO TRY

How do straight and curved surfaces reflect sunlight?

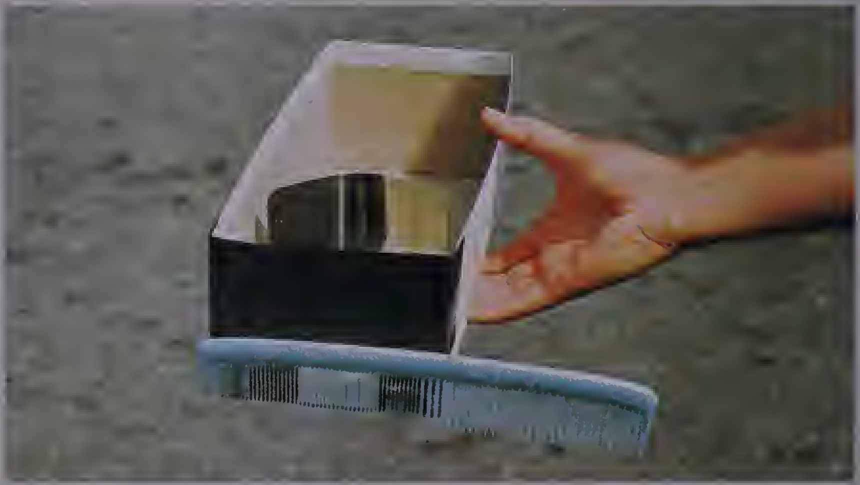
You can find out easily. First cut a long, narrow window in one end of a shoe box. Tape a comb over this window. Hold the box so the sun shines through the comb and casts lines of sun and shadow. Do all the bright lines of sunlight go in the same direction?

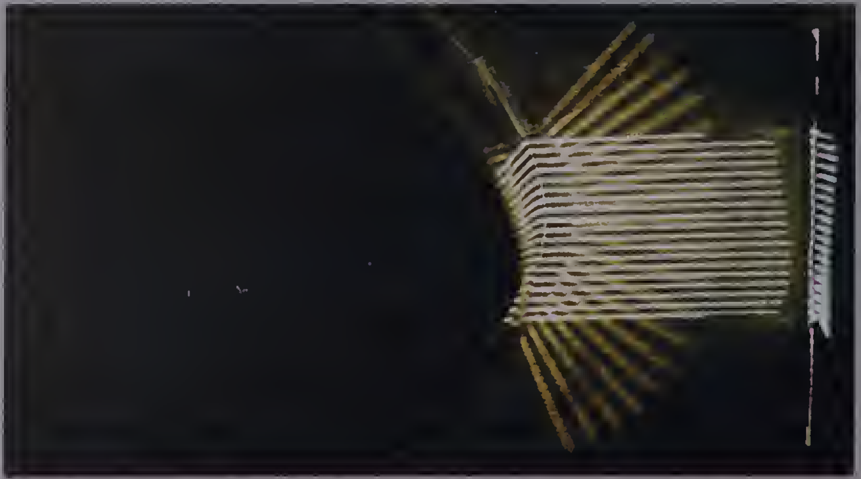
Place a flat mirror inside the box so that the lines of light strike it. Turn the mirror to the left. Then turn it to the right. What happens to the distances between the light lines as you turn the mirror? Hold the mirror so that it reflects the light directly back to the comb. Can you now see the reflected lines?

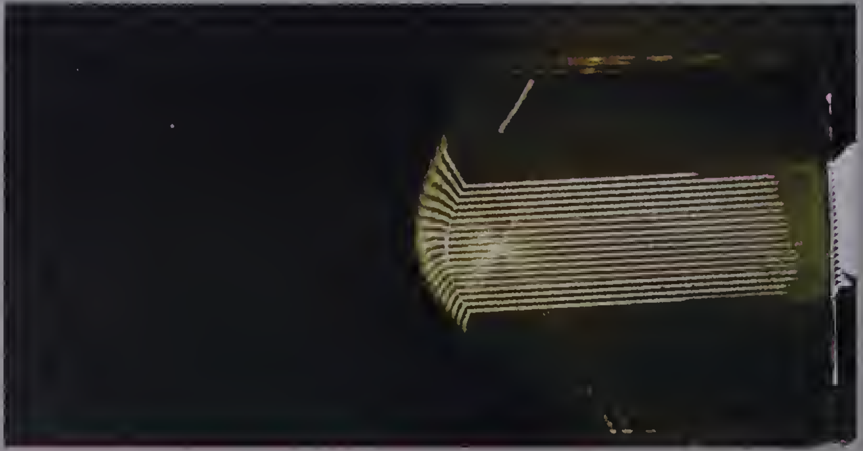
Next, try this with a convex reflector and a concave reflector. These reflectors may be made from metal mirrors which can be bent to the desired shape. You can simply bend them around a small metal can. Or you can make these mirrors by covering a large index card with foil. Bend the card into a curve. Hold it that way while you tape it to the box. You can use the same card for both mirrors. How are the lines of light reflected from a convex mirror? From a concave mirror?

You also can try this activity with artificial light sources. Direct the beam from a film projector through the comb. Is there any difference between the lines from the film projector and those from the sun? How could you explain this difference?

You may first trace the light lines from the sun on the bottom of the box. This will make it easier to compare them with the lines from other light sources.

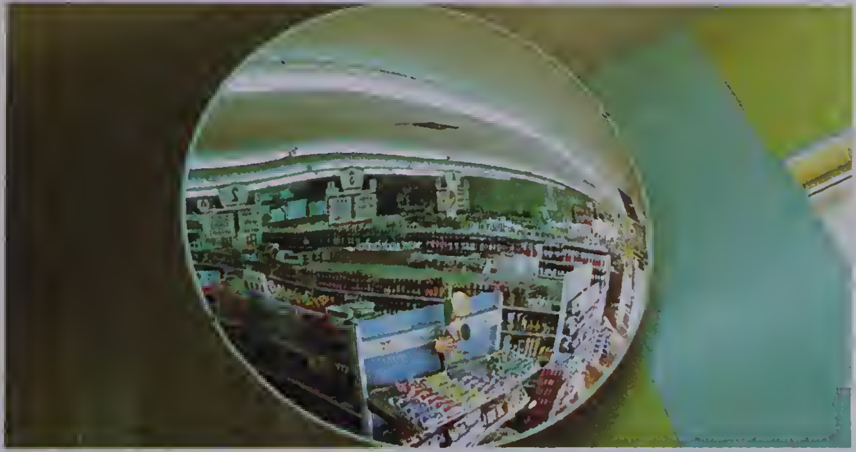




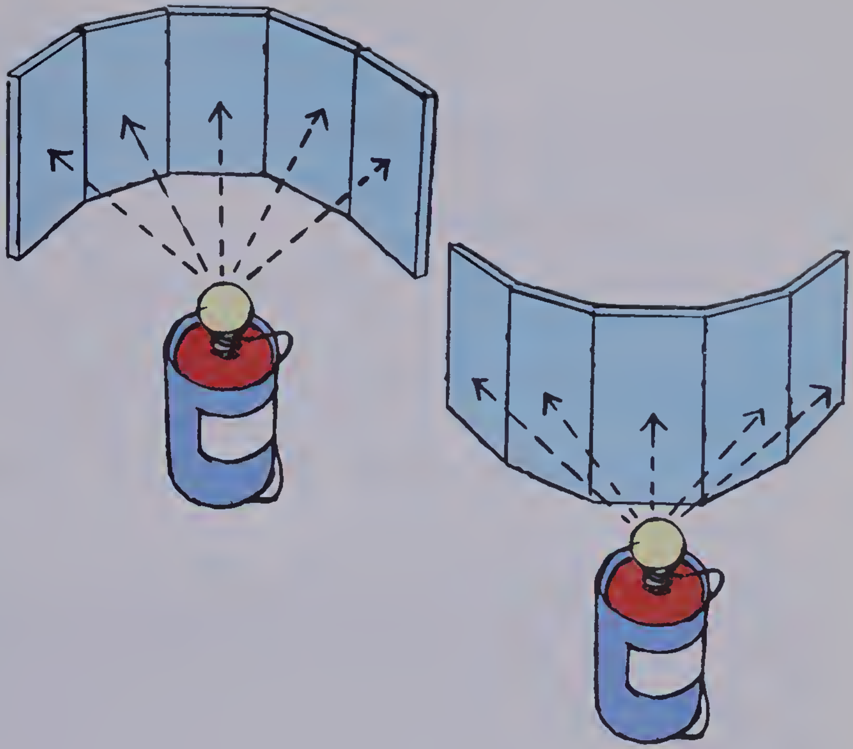


SOME THINGS TO THINK ABOUT

1. Some stores have large curved mirrors like this. These are to help clerks watch big areas of the store. Are these store mirrors convex or concave? Why?



2. This curved reflector is part of a solar furnace. It reflects energy from the sun to one point. This produces very high temperatures at that point. For this purpose, should the reflector be convex or concave?



How curved mirrors act. Suppose you taped together several small, flat mirrors, side by side. Then these would act like a larger mirror. Still, each one would reflect light just as if it were all by itself.

For example, if the little mirrors were in a straight row they would all reflect light in the same direction. But if the mirrors were in a curved row, each would reflect sunlight in a different direction. They would act like a curved mirror.

What difference would it make whether the row of mirrors curved inward or outward?

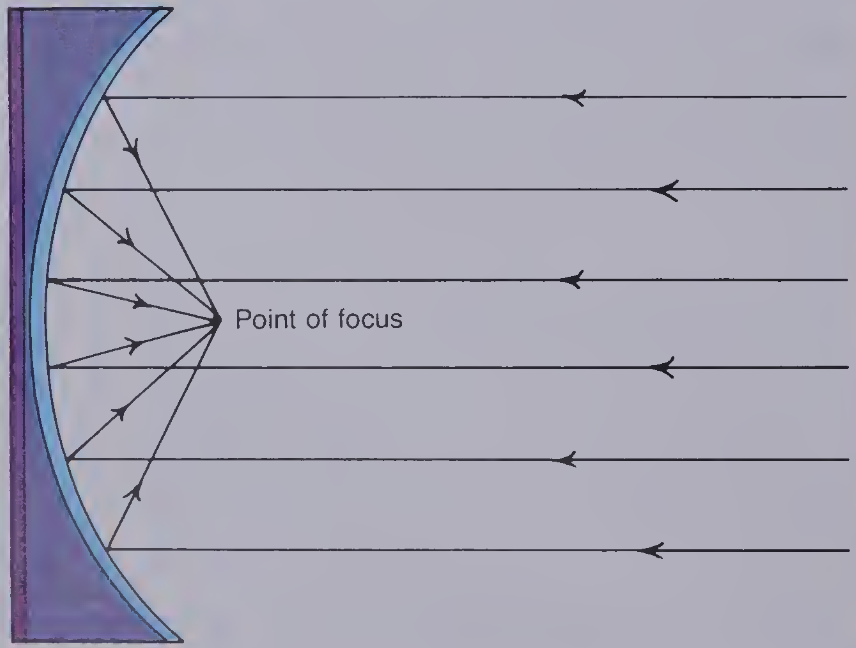
Other uses of curved mirrors. If you watch for them, you often will see curved mirrors. They are used in many ways.

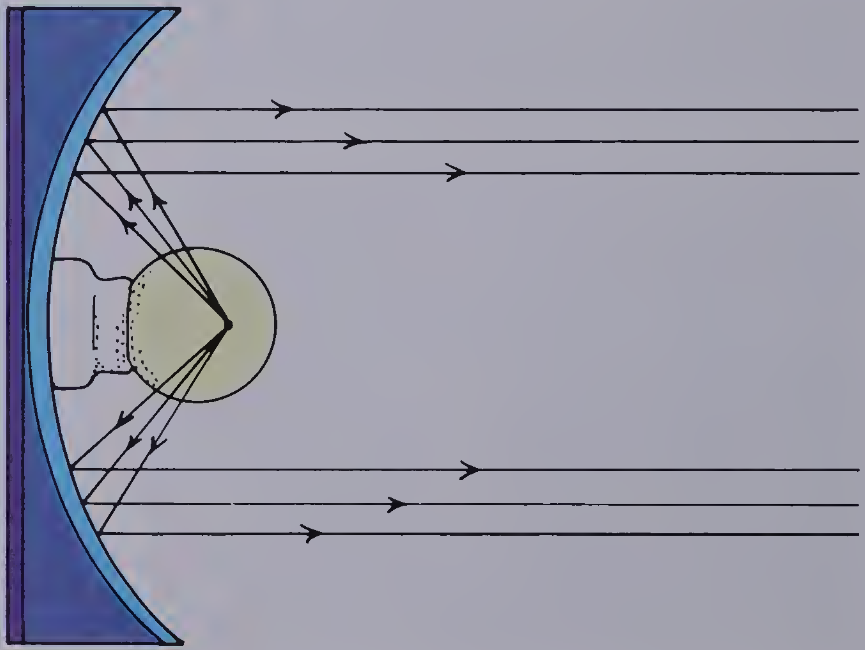
Concave mirrors or reflectors can bring light together. This kind of mirror helps *focus* the light. After it passes the point of focus, the light spreads out again. Light from the sun is very strong at his point. In a solar furnace, the energy can be used to boil water or start fires.

Concave mirrors also can be used to aim the light in a certain direction. They keep it from spreading out all around the source. The reflectors on flashlights and car headlights are used this way.

Some concave mirrors are used to make things look larger, or to magnify them. Do you have such a mirror in your home? What is it used for? Can you think of any other uses for a curved mirror that magnifies an image?

Convex mirrors in stores sometimes can make things appear smaller, or reduce them. Although they make objects appear smaller, the clerk can see a bigger area of the store. With this mirror it is possible to see almost everything that is going on in the store. Why is this important? In this kind of curved mirror, do objects look closer or farther than in a flat mirror? Or do they appear to be the same distance in both?





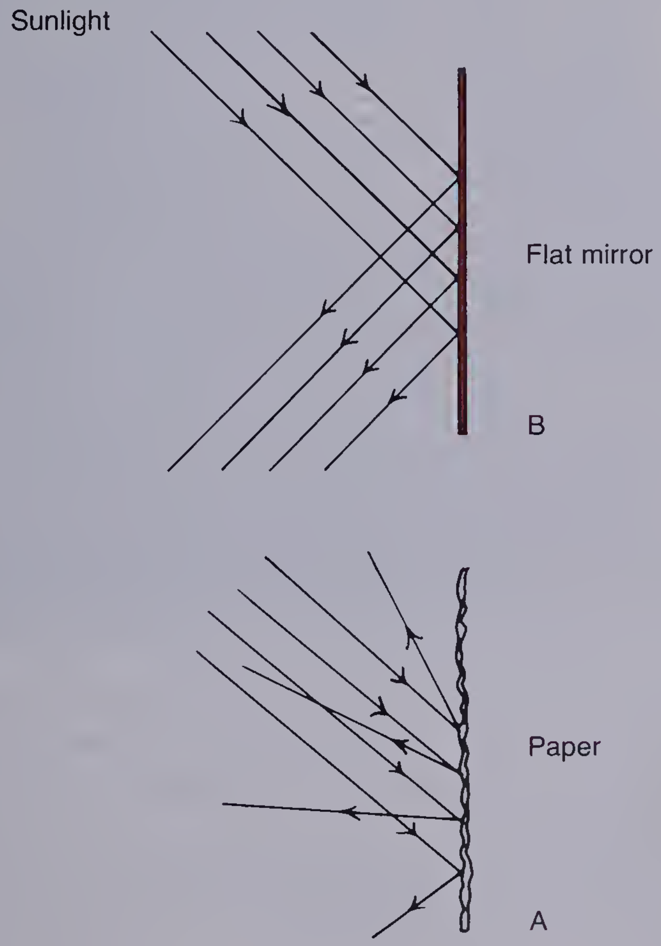
Reflection from Other Things LESSON 4

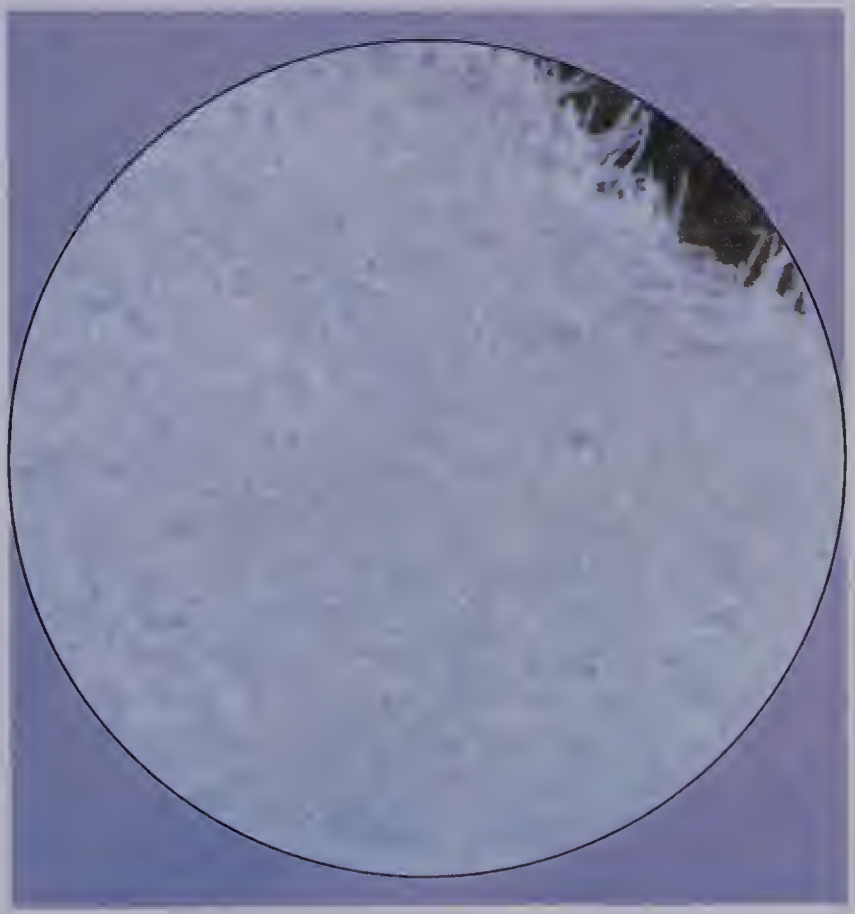
Mirrors reflect light. You can see your image clearly in a good mirror. Other shiny, smooth surfaces sometimes act like mirrors. They produce a clear, accurate image.

Most things around you reflect light. But they do not form clear images the way mirrors do. Can you see your image in a sheet of white paper? Probably not.

The paper, like most things that reflect light, does not produce a regular reflection. The surface of the paper may seem smooth. But under a microscope it looks quite rough, as you can see in the picture.

For this reason, the light it reflects goes off in many different directions. No clear image can be seen from such an irregular reflection.





SOME THINGS TO THINK ABOUT

Some surfaces give different kinds of reflections at different times. Sometimes they give a full, clear reflection. Other times they give none at all. What makes the difference?

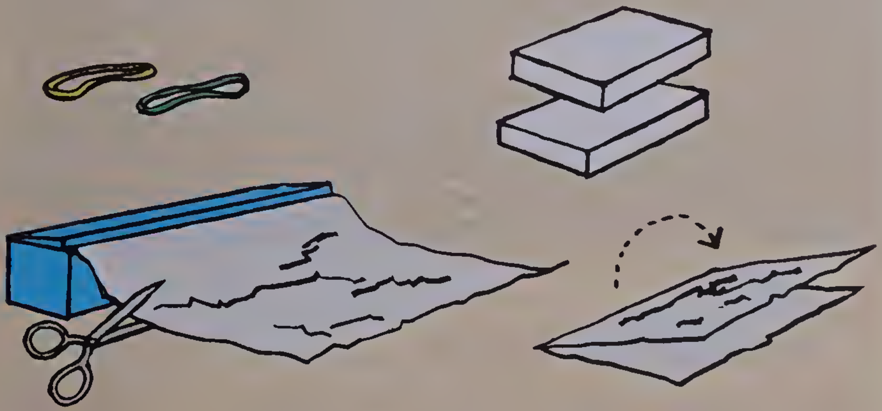
When you look out a window on a dark night, how well can you see what is outside?

If the room lights are on, you probably see your own reflection mostly. The window acts like a mirror. Can you explain why the glass is like a mirror at night? Has the glass itself changed?

At night if you are outside looking into a lighted room, how well can you see what is inside? Then does the glass act more like a mirror or a window? Can you see your reflection?

In the daytime, does a window act at all like a mirror? How could you test your answer?

Reflecting from colored surfaces. Do all things reflect the same kind of light? Do green leaves reflect the same kind of light as yellow flowers? A *photometer* can help you find out about the kinds of light reflected from surfaces of different colors. You also can use it to compare the light from different sources.



SOMETHING TO MAKE

You can make a simple photometer. Use two blocks of wax that are the same size and shape. You also will need two rubber bands and a piece of aluminum foil.

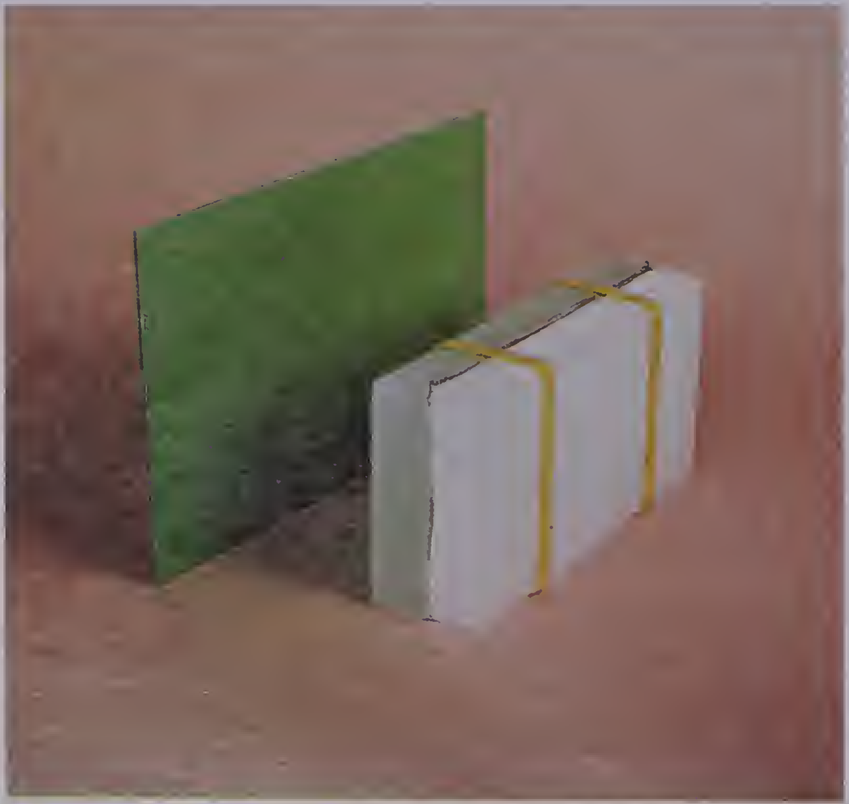
Cut the foil about twice the size of a wax block. Fold it so the shiny surfaces are on the outside. Place the foil between the wax blocks. Then use the rubber bands to hold the blocks and foil together. Now your photometer is ready to use.

Any light which reaches one side of the photometer lights up the wax on that side. Light from the other side lights up the other block. The aluminum foil stops the light from going from one block to the other. Walk around the room with your photometer. Compare how bright the wax blocks are. See if there are any color changes in the wax. What do these tell you about the light on each side of the photometer?

SOMETHING TO TRY

Use your photometer to look at the light reflected by a piece of green paper. In a brightly lit room, hold one side of your photometer near a piece of bright green paper. What color does the wax block become? How does this compare with the color of the wax block on the other side? Try holding papers of different colors on each side of the photometer. What always happens? How can you explain this?

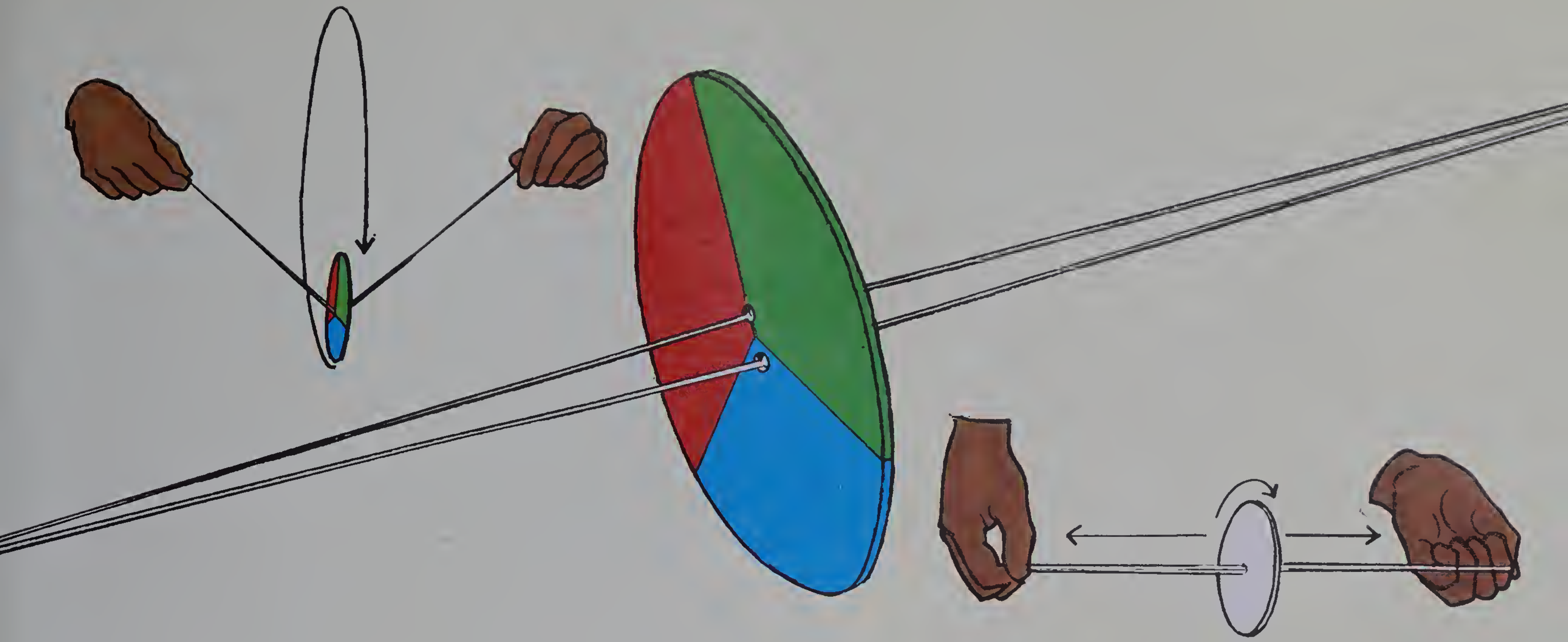
Why is green green? Reflected light is all around you. Some of it is reflected sunlight. Some is light that comes from electric lights and other sources.



Whenever white light hits a piece of green paper, green light is reflected. The green light enters the wax block and makes it look green. A red surface reflects only red light, and a blue surface reflects only blue light. Where do all these colors come from? A rainbow gives us the answer.

On a sunny day, have you ever seen a rainstorm in the distance? Sometimes when this happens, the white sunlight is broken apart by tiny drops of water. It is broken into all the colors of the rainbow. The white sunlight has all these colors. When they are together, they look white.

A green paper separates green from the other colors in white light. It "soaks up" all the other colors and reflects only green.



SOMETHING ELSE TO TRY

Experiment with a spinning color wheel. If white light contains many colors, can we mix colors together to produce white?

Cut a 9-cm circle from cardboard. Divide the circle into three equal parts. Using crayons or paint, color one section solid blue, the next solid red, and the third section solid green.

With a sharp pencil, punch two small holes in the wheel. Each should be about 3 mm from the center.

Run one end of a string about 1.5 m long through one hole and out through the other. Tie the ends of the string together. Move the wheel so that it is halfway between the two ends of the string.

Then wind up the strings. Hold each end, and make the wheel travel in a circular path so that the strings twist.

Now spin the wheel. Gently pull the strings out from the wheel, back and forth. Watch the colors closely as you do this. It may take a little practice to get the wheel started.

When the wheel is turning fast, does it look almost white? Your eyes are adding the three colors together to give this whitish color.

Try blending different sets of colors. What new colors do you see as the wheel spins and your eye mixes the separate colors?

Ideas for REVIEW

- Some things, such as the sun, candles, and electric lights, produce light.

- Many other things, such as a piece of paper, only reflect light.
- Light travels in straight lines. It does not go around corners.
- A beam of light directed to a mirror is reflected off at the same angle it hit the mirror. However, it does not go off in the same direction unless it hits the mirror straight on.
- Images seem the same distance behind the mirror as the object is in front.
- Images in a concave curved mirror look right side up and larger, if close. They look upside down and smaller, if far away.
- A convex mirror makes images look right side up and smaller.
- Concave mirrors bring light to a point of focus. The light then spreads out. They also can send a beam of light in one direction, as with a flashlight.
- Convex mirrors spread light out.
- White light contains all of the colors of the rainbow.
- A piece of green paper "soaks up" all the colors but green.
- Colors can be mixed on a spinning wheel to produce white.

TEST Your Understanding

A. Choose a word from column B that best matches the words in column A. On a piece of paper, write the letter of the word next to the number it matches. *Do not write in this book.*

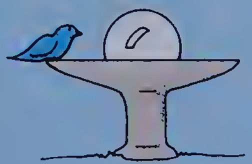
A

1. needed for sight
2. face in a mirror
3. can be broken up by raindrops
4. a TV screen
5. the inside of a bowl
6. reflector
7. image in top of a spoon
8. producer of light
9. reflected by blue paper
10. where light comes together

B

- **a.** convex
- **b.** light source
- **c.** light
- **d.** concave
- **e.** focus
- **f.** white light
- **g.** blue light
- **h.** mirror
- **i.** image
- **j.** upside down

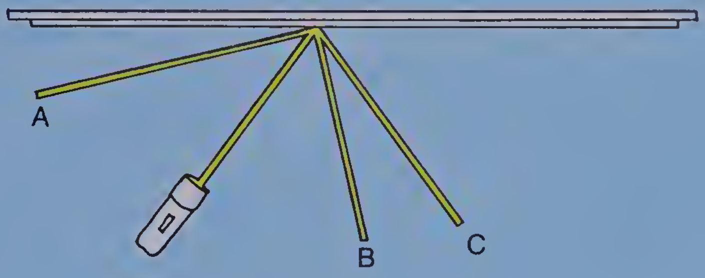
B. Write the answers to each of the following questions on your paper.



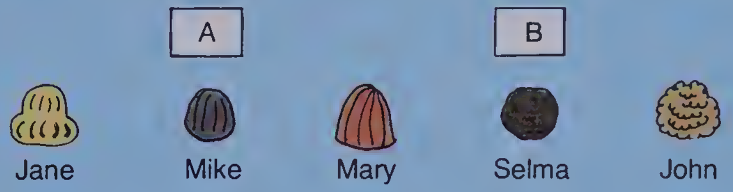
11. What kind of mirror is in this birdbath?

12. Will the birds see smaller or bigger birds when they look into the birdbath?

13. A flashlight shines on the mirror below. Which of the beams shown would you expect to be reflected?



14. Whom do you think Mary sees in mirror A?

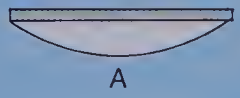


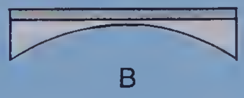
15. Whom do you think Mary sees in mirror B?

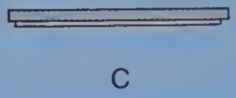
16. Which people can see Mary in a mirror?

17. Which people cannot see Mary in a mirror?

C. In numbers 18, 19, and 20, tell whether mirror A, B, or C would give the desired image.





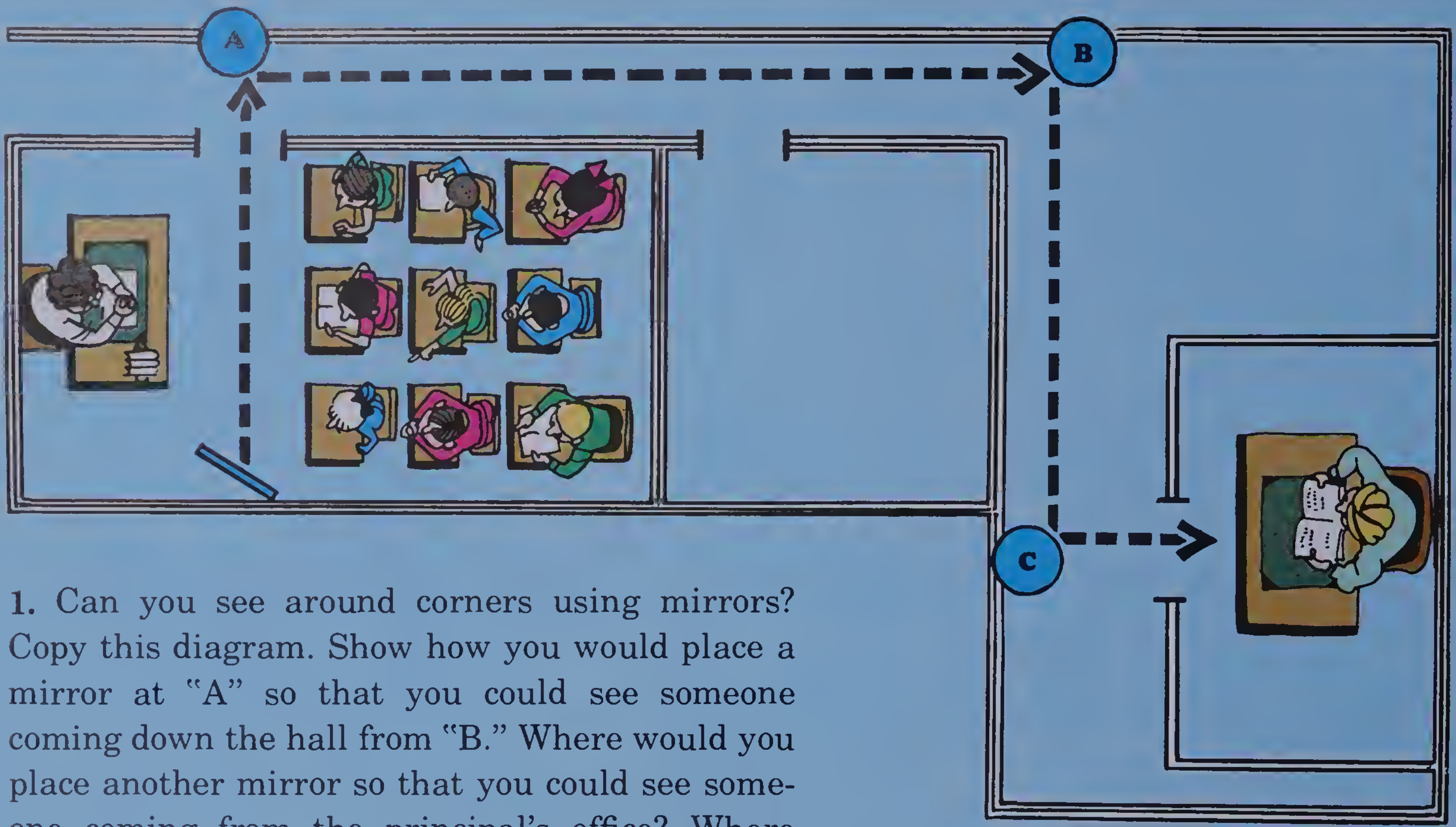


18. a magnified image that is right side up

19. a smaller image that is upside down

20. a wider view that is right side up

PROBLEMS

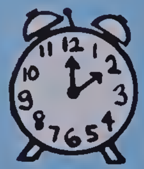


1. Can you see around corners using mirrors? Copy this diagram. Show how you would place a mirror at "A" so that you could see someone coming down the hall from "B." Where would you place another mirror so that you could see someone coming from the principal's office? Where could the principal place mirrors so that she might see you?

2. If you were to stand a mirror on the dotted line, which words would look the same in the mirror? Think of some other words that would read the same when reflected by a mirror.

FRANK DO YOUR DEED

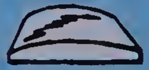
3. What would the image of this clock look like

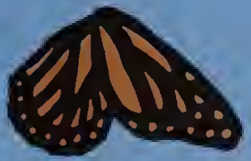


a. in a single flat mirror?

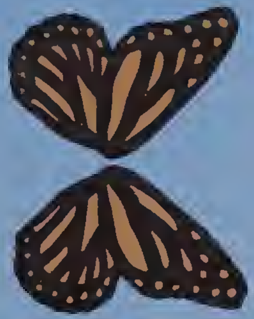
b. in a concave mirror?

c. in a convex mirror?

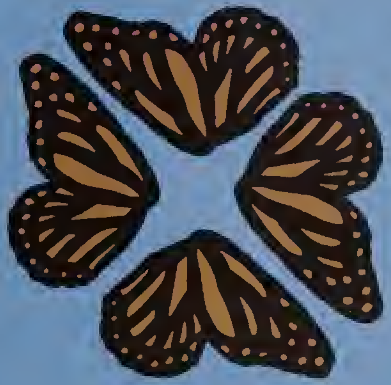




A



B

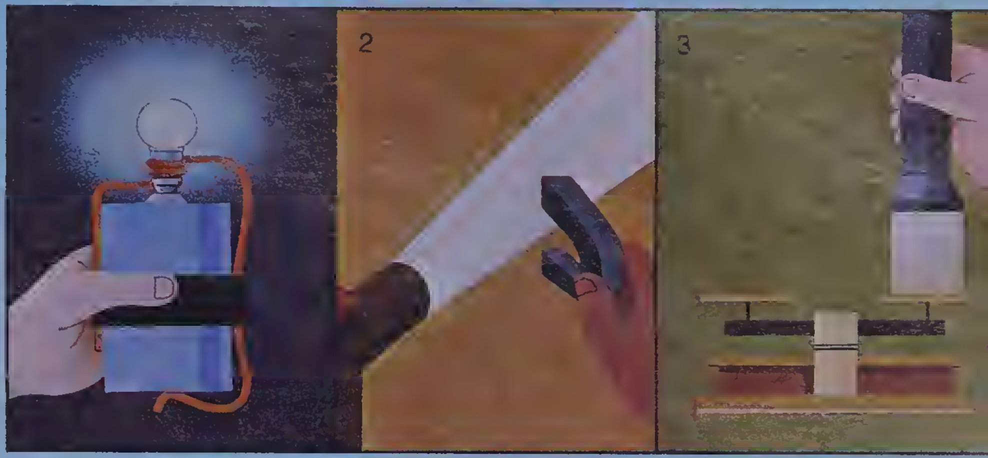


C

4. Where would you place mirrors by pattern A in order to see pattern B? Pattern C?

5. If you want to see all of yourself in a mirror, what is the shortest mirror you could use? Explain how you decided on the answer.

FIND OUT on Your Own



1. From how far away do you suppose you could see this little light on a clear, dark night? From a block away? From a kilometre away? From even farther away?

Try to find an open area where you can see a long distance.

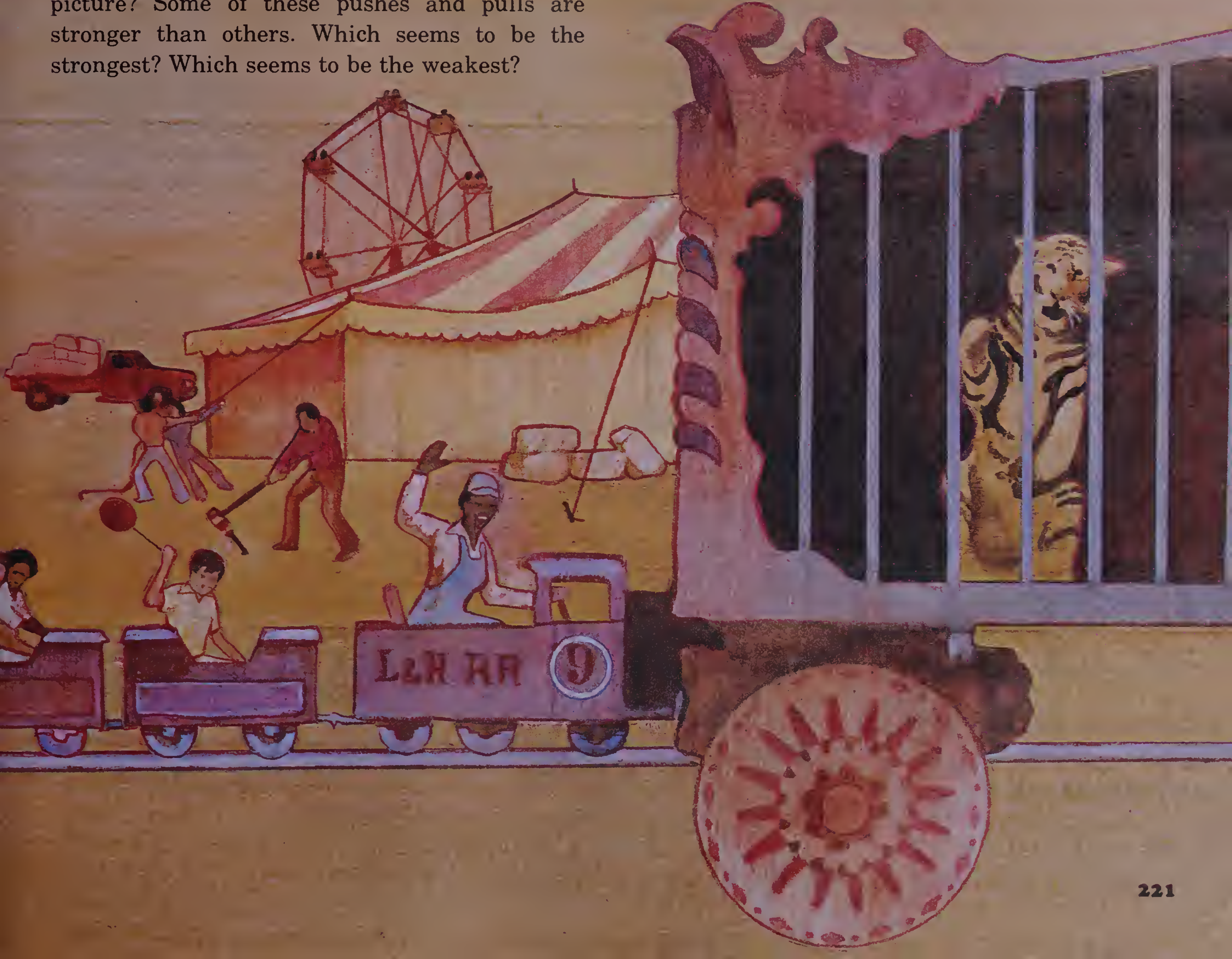
2. What would you guess this strong magnet will do to the beam of light? Suppose you have a strong magnet, and try this yourself, but nothing happens. Might a stronger magnet have an effect? Try this with the strongest magnet you can find. Try light beams from flashlights and penlights too.

3. Is light a kind of matter? Does it have mass? Direct a strong light beam onto one pan of a sensitive balance scale. Does it make the pan go down at all? If not, does this prove light does not have mass? Why or why not?

8 Forces and Motion

Wherever you look, things are pushing and pulling on each other. In this picture, for example, an elephant is shown pushing a wagon. And an engine is pulling a small train.

What other pushes and pulls can you find in the picture? Some of these pushes and pulls are stronger than others. Which seems to be the strongest? Which seems to be the weakest?



Forces All Around Us LESSON 1

Pushes and pulls are called *forces*. There are thousands of forces acting all around us. They act on all sorts of things.

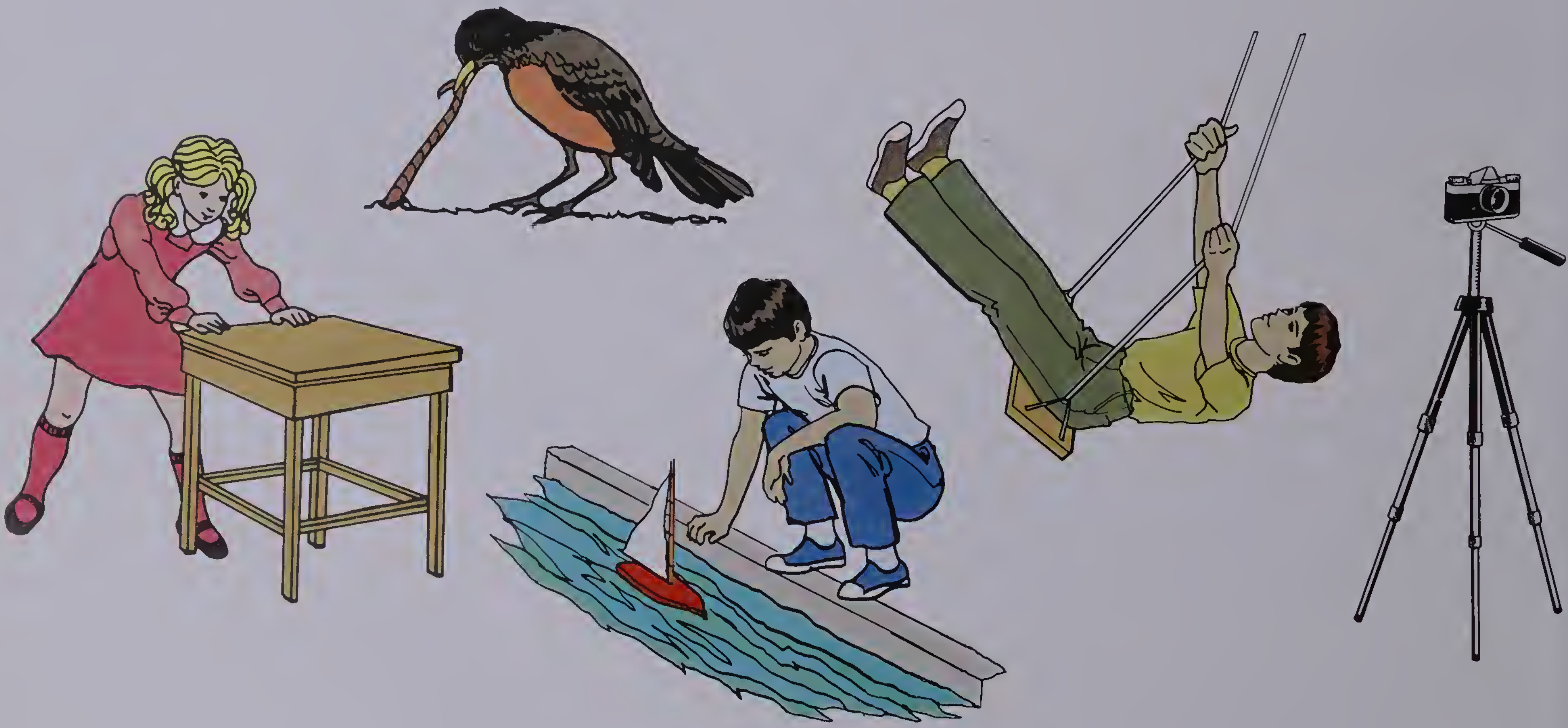
You use, or *exert,* a force when you open a door or window. You also exert a force when you close the door or window. You exert a force on a wagon when you pull it. You exert a force on a shopping cart when you push it. You exert a force on a chair when you sit down on it. What happens when you sit on a chair without moving? Do you exert a force then?

In these pictures, what forces are being exerted? On what objects are they acting? How can you tell?

Which of these forces are pushes? Which are pulls? In what directions are these forces acting? Which seems to be the strongest force in the picture? Which seems to be the weakest?

Give an example of each of the following:
- forces causing things to move
- forces stopping things from moving

What other effects can forces have?



SOME THINGS TO TRY

Here are some ways to compare the strength of forces.

1. Put a smooth layer of soft clay in a pan. Get two marbles that are the same size. Drop them on the clay from different heights. Which marble exerts a stronger force on the clay? How can you tell?

What will happen if you drop both marbles from the same height? If you drop a marble and a steel ball of the same size from the same height? Try it.

2. Find two long, thin rubber bands that are just alike. Cut each of them once. Then you will have two equal strips of rubber. Tie a short piece of string tightly to each end of each strip.

You now can use these strips to make fair tests of different forces. See how much each force makes the rubber stretch. For example, compare the forces needed

- to make two similar boxes slide—one empty and the other loaded with blocks
- to move two similar blocks—one that slides and one that rolls on drinking straws
- to roll a toy truck or car along the floor, and to lift it straight up
- to lift two stones or other objects off a table or the floor

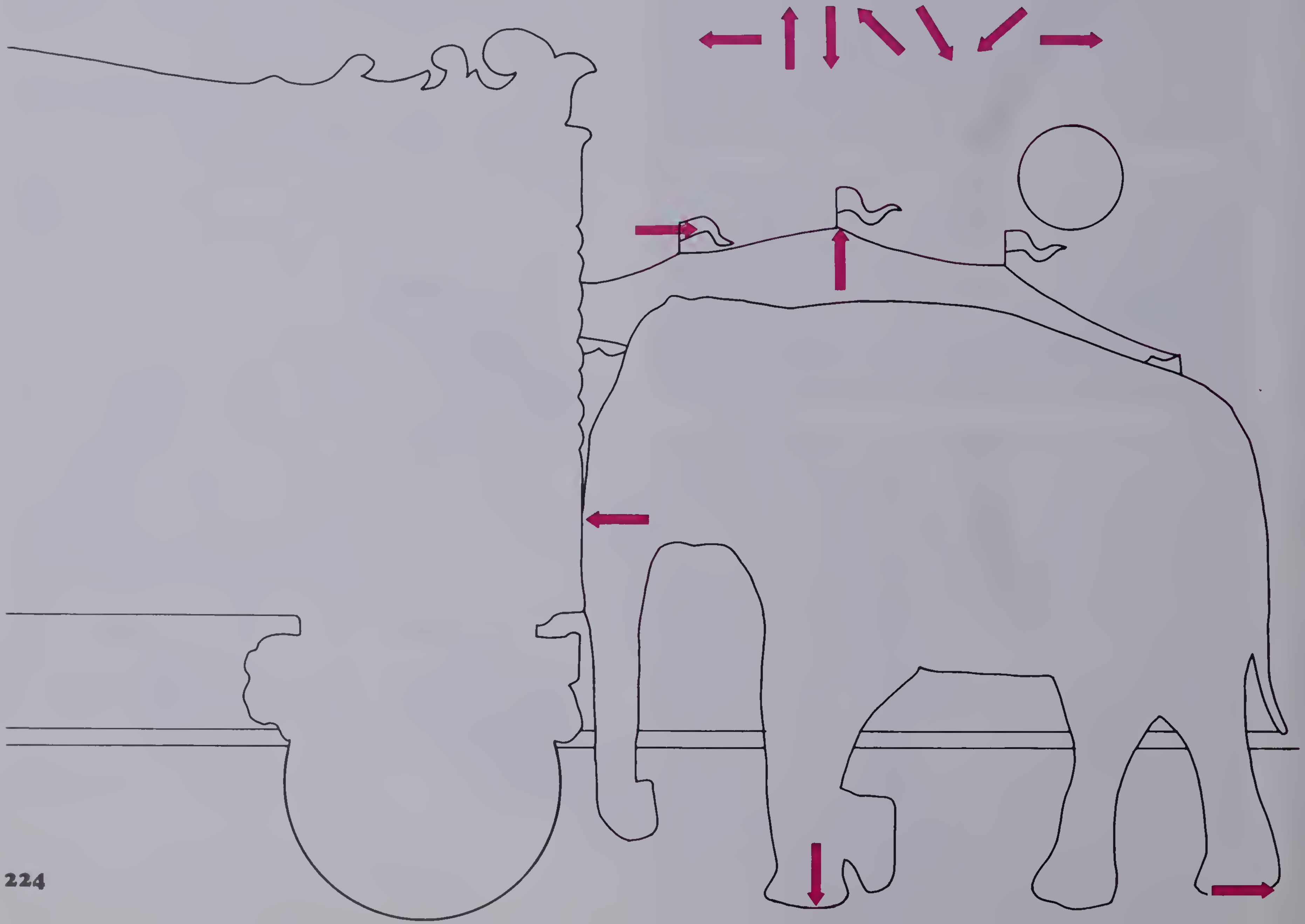
You might also try this: pull similar roller skates up sloping boards, one steeper than the other.

In each case, why is there a difference in the strengths of the forces?

Direction and strength of forces. Now turn back to the picture on pages 220 and 221.

How many forces are you able to find in the picture? On what are these forces acting? What are the forces making some of these things do?

Now look at the drawing on these pages. Arrows have been added to stand for some of the forces. These arrows show the directions in which the forces are acting. Can you find a force that is acting in each of these directions?



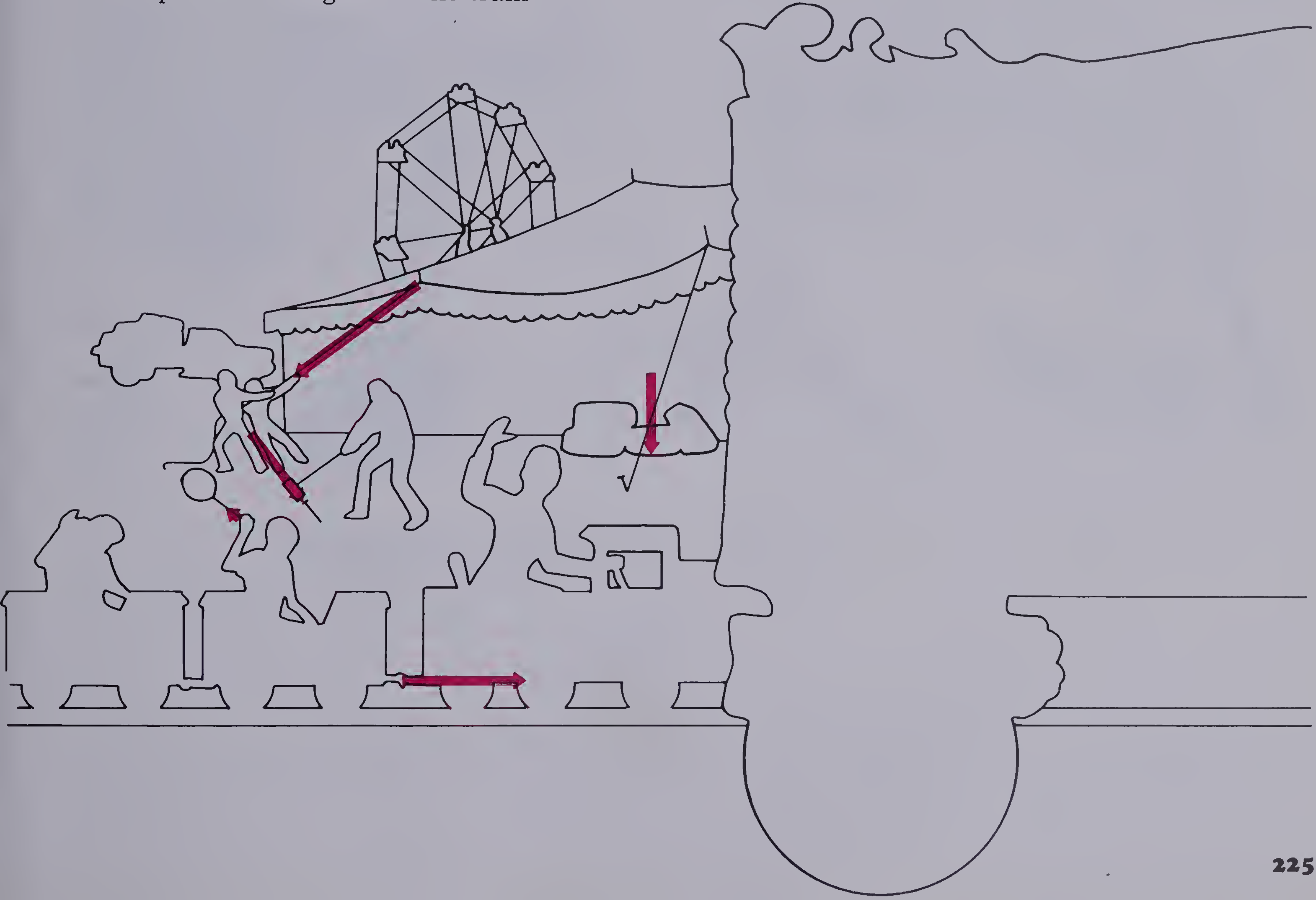
You also can tell from the arrows which forces are stronger than others. How?

For example, how do these three forces compare in strength?

- the pull of the workers on the tent rope
- the push of the hammer on the tent stake
- the pull of the engine on the train

Force vectors. It often is useful to show a force by an arrow. An arrow like this is called a *vector*.

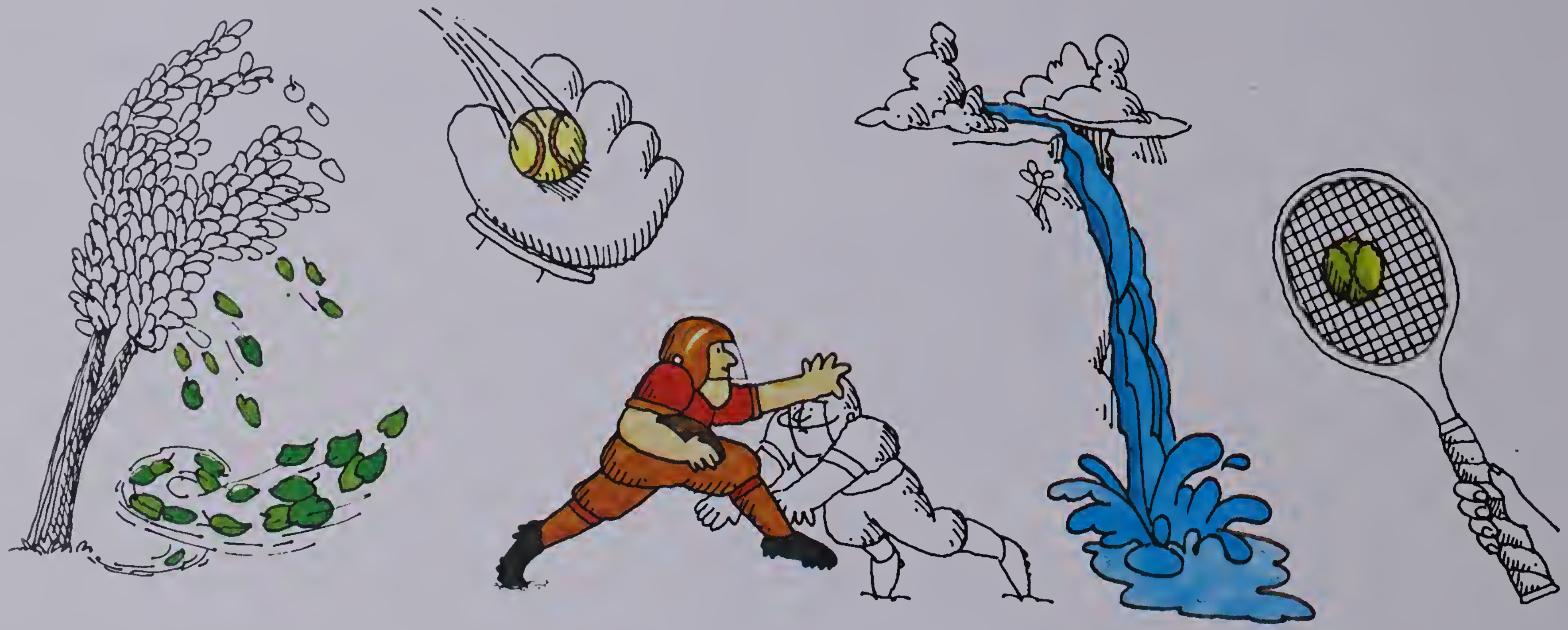
A vector shows the direction of a force by the way it points. And it shows the strength of the force by its length.



What Forces Do LESSON 2

In these pictures, the things shown in color have forces acting on them. What are these forces? What effects do they have on the motions of the things shown in color?

Forces often make things start to move. But sometimes they make moving things stop or slow down. And they may cause the motions of things to change in other ways, too.



SOMETHING TO THINK ABOUT

Think of some forces—pushes and pulls—that make things

- go faster
- go slower
- change direction
- start to turn
- turn faster

SOME THINGS TO TRY

How can forces on a ball cause changes in its motion?

1. Place a small ball on a level desk. Then blow it from the side. What pushes on the ball and makes it start moving?

Once the ball is moving, can you stop it by blowing? Make it go faster and faster? Make it slow down? Make it change direction?

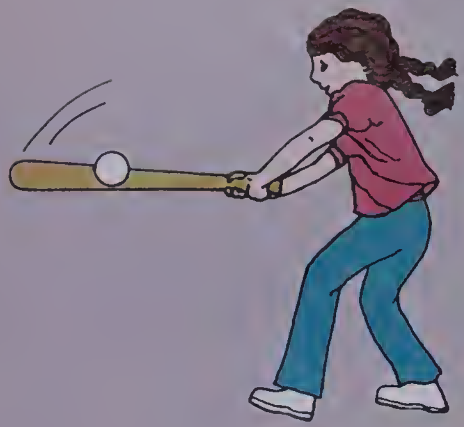
These are five different ways in which you can change the motion of the ball. Each change in the ball's motion is caused by a force acting on it.

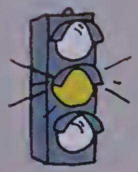
Besides blowing, how else can you make a force act on the ball and change its motion? Can you pull on it in any way?

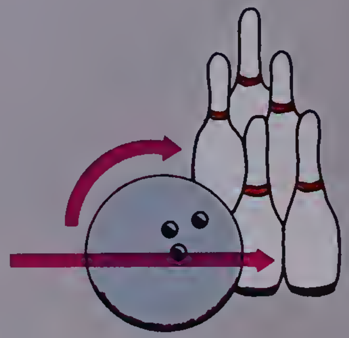
2. Try to make a steel ball start moving by bringing a magnet near it. Once the ball is moving, can you use the pull of the magnet to make it stop?

Can you make the ball go faster with the pull of the magnet? Can you make the ball slow down or change direction?

3. Let a ball roll off the edge of a desk. How is the direction of the ball changed? Where does this change take place? Which way must a force be acting on the ball to cause this change in its motion?







Forces and changes in motion. Forces often change the motions of things. For example, this is what happens when a baseball bat hits a baseball. The push of the bat changes the motion of the ball. In what ways does it change the motion of the ball? In what other ways is the motion of the ball changed during a baseball game?

What changes can you cause in the motion of a toy truck? What changes can you see in the motions of real trucks? Road signs and traffic lights often give clues to these changes in motion.

Changes in motion often take place with things that move from place to place, like boats and airplanes. They also take place with things that turn around in the same place, like record players. These things, too, may be made to start moving, speed up, slow down, and stop.

What about things that move from place to place and turn around at the same time? Bicycle wheels and bowling balls do this. Can you think of other things? What kinds of changes in motion may these things show?

Forces without changes in motion. Forces also may act on things without causing any changes in motion. For example, a dog may pull on a sled, yet not be able to start it moving. Also, when you are sitting quietly, you are pushing downward on your chair. But its motion does not change.

The balloon in the picture may or may not be changing its motion. If not, what forces are acting on it? What might cause the balloon to change its motion? What forces are acting on the desk? Do you think that it makes any difference whether or not the desk is moving?

Even moving things have forces acting on them that do not cause any changes in their motion. For example, you have to pull on a wagon to keep it going straight ahead. The wagon moves. But its motion does not change. Why not?

The reason is that your pull on the wagon is just equal and opposite to certain other forces acting on it. For example, the force of *friction* causes the wheels to drag a bit. Your pull and these other forces match one another. Therefore, the motion of the wagon does not change.

Other changes caused by forces. Sometimes, forces do not change the motions of things. But they may cause changes in the things themselves. They may make things bend or stretch. They may squeeze things into different shapes. They may even break or pull things apart!

The pictures above show how forces can cause some things to change. The clay can be changed into many different shapes. Each change is caused by pushes in certain directions. What kinds of pushes would make a flat "pancake"?

Weight as a Force LESSON 3

Have you ever thought of weight as a force?

Objects and the earth pull on each other. This force between them is known as *gravity*. Gravity causes objects to have weight.

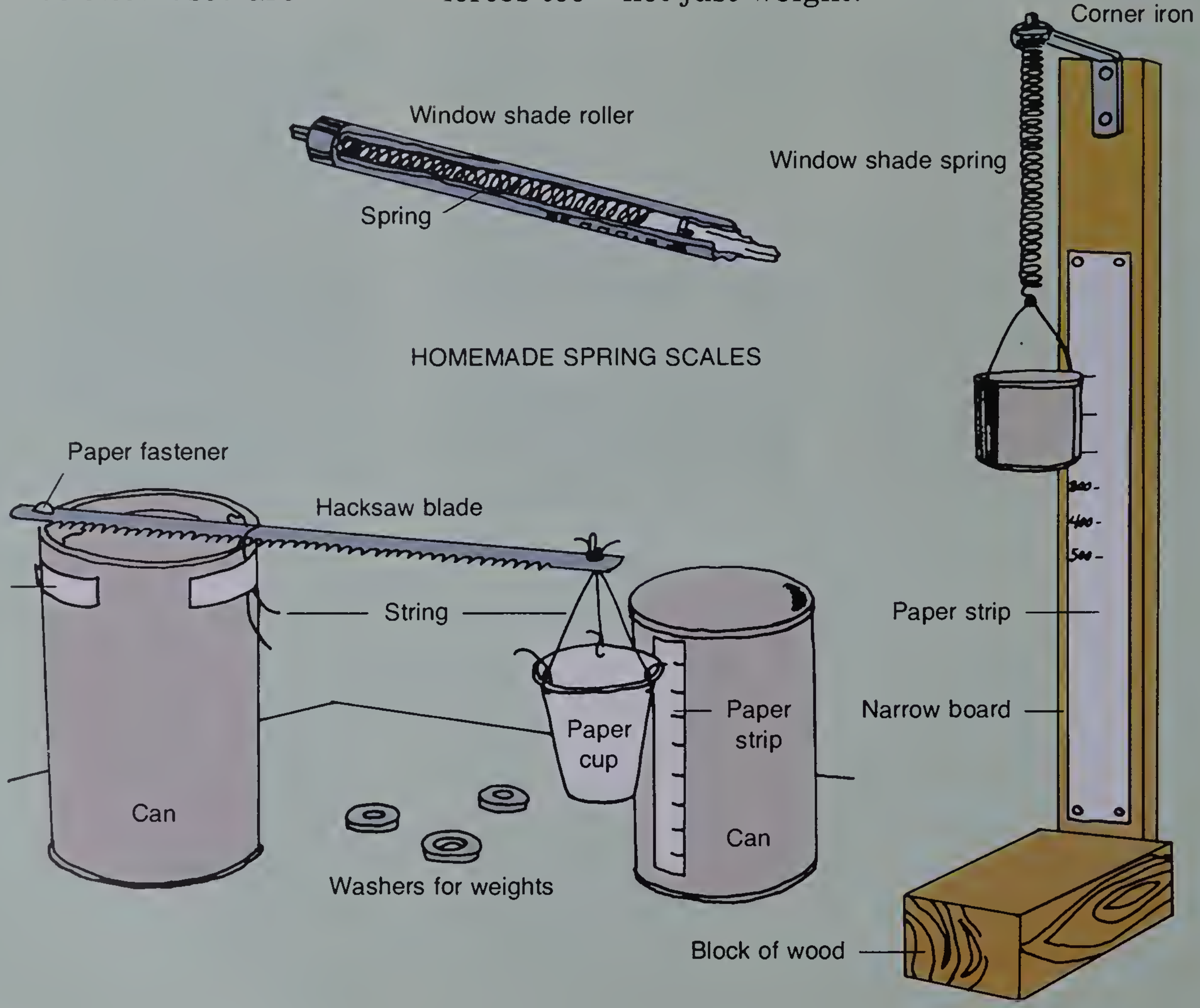
To find the weight of things we usually use *scales* or *balances*. Two kinds often used are

- spring scales
- beam balances

Spring scales. These have springs that stretch or bend when objects are hung on them. The more the objects weigh, the more the springs stretch or bend.

Spring scales often are used to measure other forces too—not just weight.

COMMERCIAL SPRING SCALES

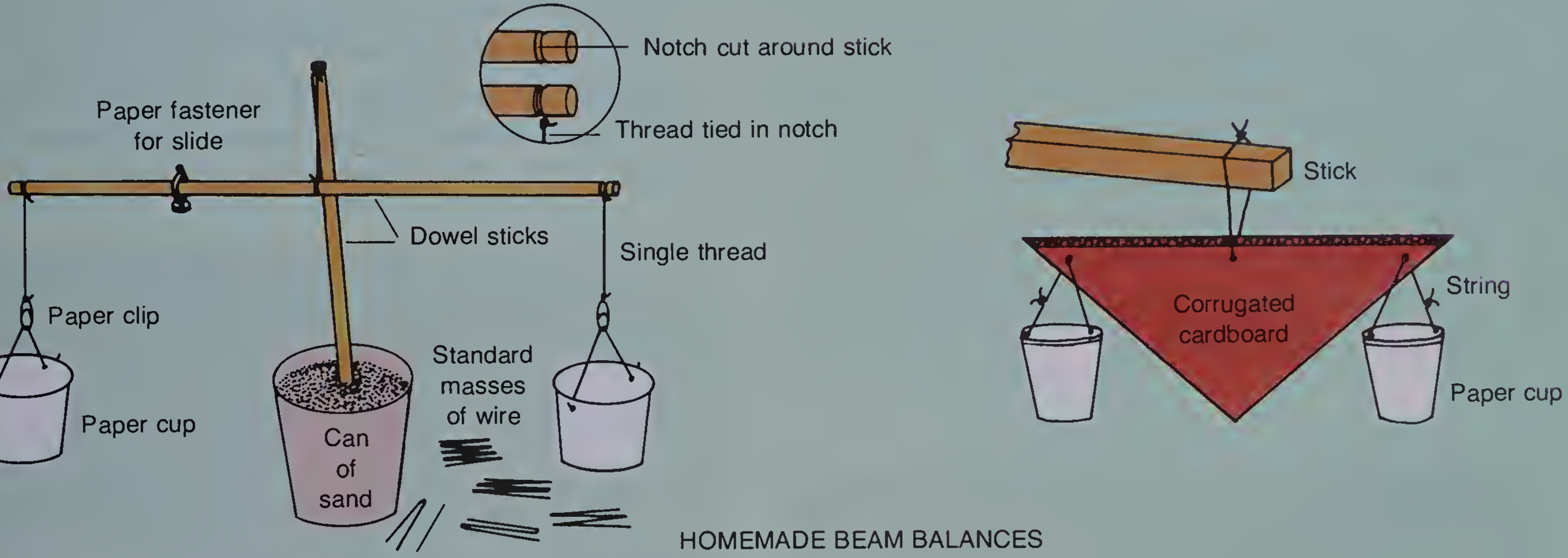


HOMEMADE SPRING SCALES

Beam balances. These act like seesaws. They compare the weights of objects placed on the two sides of the *beam*. When the beam is level, it shows that the objects weigh the same.

This means that the objects have equal amounts of matter in them, or equal mass.

COMMERCIAL BEAM BALANCES



HOMEMADE BEAM BALANCES

SOME THINGS TO INVESTIGATE

Choose one of the following questions. Then try to find the answer with the help of a spring scale or beam balance.

Measure carefully. Be sure that everything is fair. Do not trust your memory—keep written records!

- What brand of soap gives you the most for your money?
- Which weighs more, a dry sponge or the water it can soak up?
- What happens to the mass of a candle as it keeps burning?

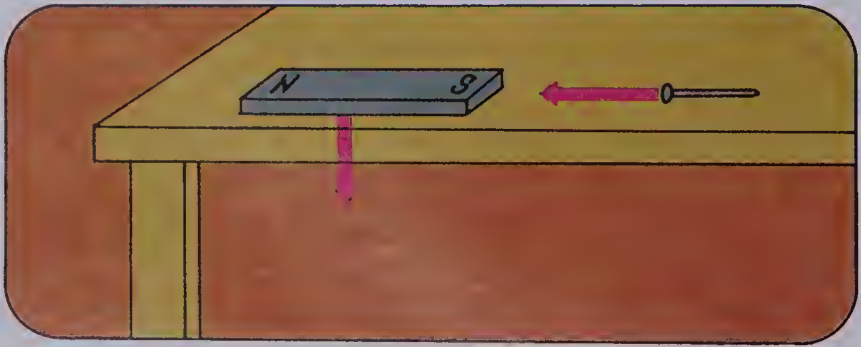
Safety Note: *Do not burn a candle on any kind of hanging balance. Use only an open platform balance. Be sure an adult is present when you do this.*

More than one force. When a magnet lies on a table, it pushes downward against the table. What causes it to push against the table?

Now, if a nail is placed nearby, the magnet pulls on it. Then the magnet pushes against the table and pulls on the nail—both at the same time!

This shows that something may exert more than one force at the same time. It may exert a downward push or pull because of its weight. In addition, it also may exert a force in a different direction.

What things can you think of that exert several forces at the same time? Is one of these forces always the object's weight?



SOME THINGS TO TRY

1. What forces does a bicycle exert?

Hold a bicycle upright on a smooth floor. Rest its rear wheel on a sheet of cardboard.

When this wheel is not turning, which way does it push against the cardboard? What causes this push? What does it tend to do to the cardboard?

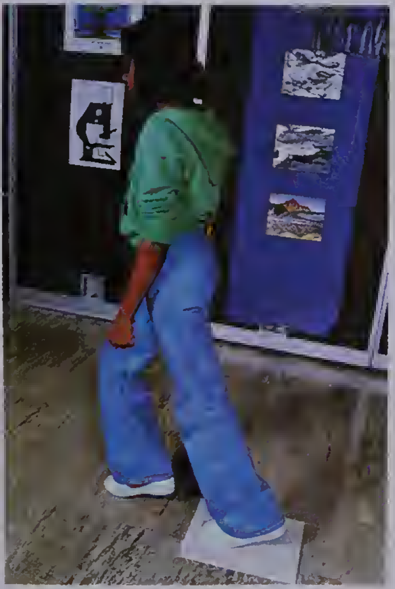
Now, keeping the bicycle in place, make its rear wheel turn. As the wheel turns, which way does it push against the cardboard? How can you tell? At the same time, does it still push downward against the cardboard? How can you tell?

2. In what directions do you push against the floor?

Place a sheet of wax paper on a smooth floor. Lay a sheet of cardboard on top of it. Then stand on the cardboard.

Because of your weight, which way do you push against the cardboard? What does your force tend to do to it?

Now take a very big step ahead. When you do this, what happens to the cardboard? Why is this? Does the floor also push downward against the cardboard? When you walk, in how many directions do you push?



Forces when things move ahead. Because of its weight, the wheels of a bicycle push downward against the ground. But when the rear wheel is turned, it also pushes backward against the ground.

Because of your weight, you push downward against the floor. When you step ahead with one foot, your other foot also pushes backward against the floor.

Suppose that the rear wheel of a bicycle did not push backward. Could the bicycle move forward? Why or why not? Suppose that your feet did not push backward. Could you walk forward? Why or why not?

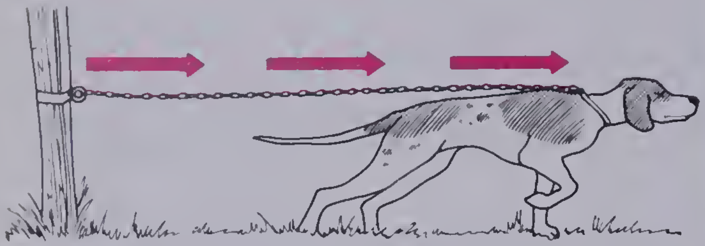
How can the rear wheel of a bicycle push backward against the ground? Or how can your shoes push backward against the floor? It is because of friction!

There is friction between the bicycle tire and the ground. There also is friction between your shoes and the floor. If it were not for this friction, do you suppose that you could move ahead?

SOMETHING TO THINK ABOUT

Many things push backward as they move forward. This is true of snowmobiles and swamp buggies, and of snails and snakes.

Just how does each of these things push backward? Against what does it push?



When a dog pulls on its chain, its force acts along the whole chain. The first link pulls on the second. The second pulls on the third, and so on. What would happen if just one link were to break?

When a locomotive pulls on a train, its pull is passed along from car to car. The cars *transmit* the force from one end of the train to the other.

If the train backs up, the cars again transmit the force of the locomotive. But this time, is the force a pull or a push?

When a train is pulled or pushed, is the strength of the force acting on each car the same? Is this also true when a dog pulls on the links of its chain? Why is there a difference?

These examples show that forces may be transmitted from one object to another. Where else have you seen forces being transmitted?

SOME THINGS TO TRY

Get five or more rubber bands that are as alike as you can find. Then connect them to make a chain.

Now watch what this chain does when it is pulled in different ways.

1. What happens to the chain when you pull on its ends in opposite directions?

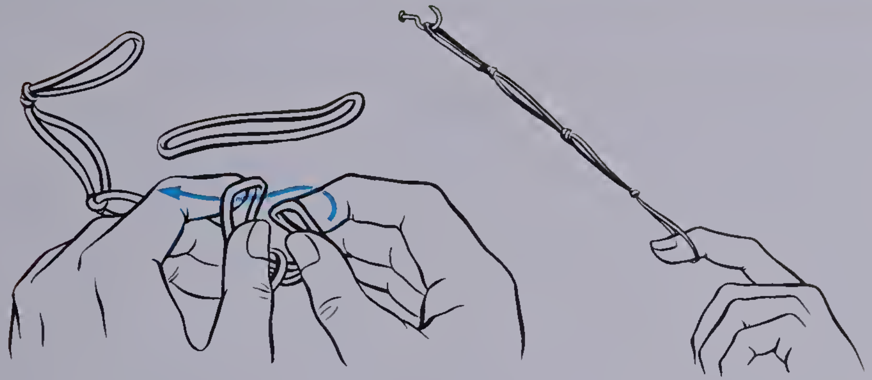
Does each rubber band stretch about the same amount?

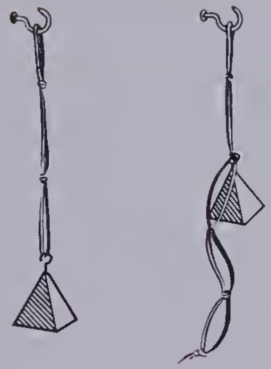
Or do the two end ones stretch more than the others?

2. What does the chain do when you hang one end on a hook and pull on the other end?

Do the rubber bands all stretch about the same amount?

Or does the one you pull on stretch more than the others?





3. Are you able to make the chain stretch by pulling on only one end?

Or must something pull on its other end at the same time?

Is something that just holds its other end pulling on it?

4. What happens when you hang the chain on a hook and hold up a heavy object with it?

How much do the pulls make each rubber band stretch? Does any one of the rubber bands stretch more by itself?

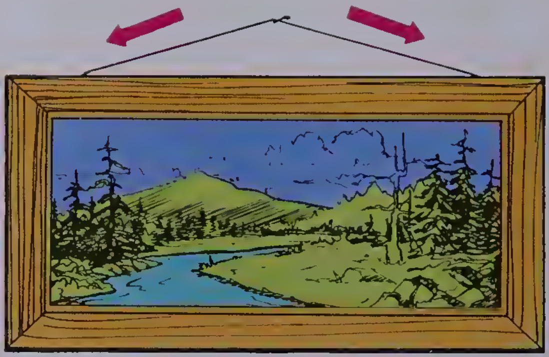
5. What does the chain do when you use it to pull a box filled with blocks?

Then how many pulls are acting on the chain?

How do these pulls compare in direction and strength?

6. What happens when you pull a "train" of boxes connected by similar chains of rubber bands?

Do the rubber-band chains all stretch about the same? Or do some of the rubber-band chains show stronger pulls than others?



Strength of materials. Forces often are transmitted through things that do not have separate parts. For example, a push or a pull may be transmitted by a stick or by a wire. What other examples can you think of?

However, sticks and wires, like all materials, are made up of very tiny particles. These particles transmit pushes and pulls through the materials. When a force acts on a material, it is transmitted from one particle to another.

Of course, some materials can transmit greater forces than others. We say that these materials are stronger than others. The strength of a material depends on how well its tiny particles hold together. It also may depend on how easily they slip past one another.

For example, if your shoelace is not strong enough to transmit your pull, it breaks. And if the point of your pencil is not strong enough to transmit your push, it breaks, too. Once the particles become separated, they can no longer transmit forces.

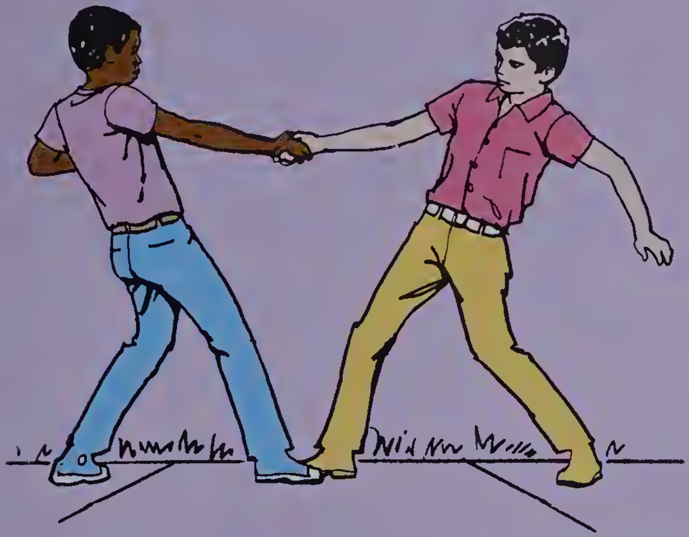
Forces Acting in Pairs LESSON 5

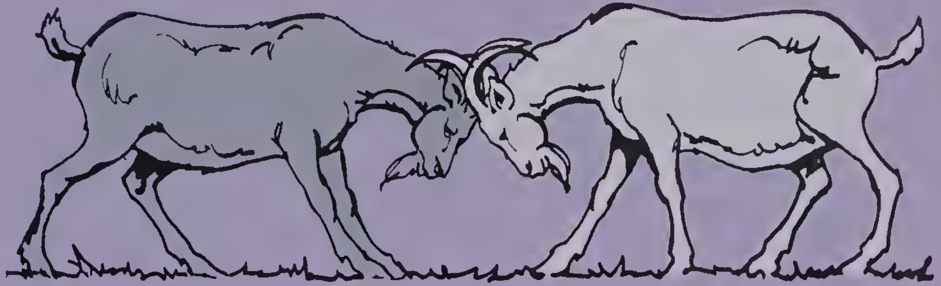
The things and people shown in these pictures are pushing or pulling on one another. Which ones do you think are pushing? Why? Which ones do you think are pulling? Why?

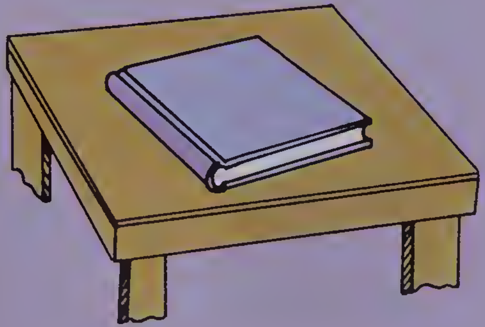
What would happen if the boys' hands were to slip apart? What if there were no desk under the book, pushing upward against it? Or what if the hook came loose from the wall?

Suppose the girl missed the ball. Then could the paddle push against the ball? Would the ball be able to push against the paddle?

The pictures show examples of a very important idea in science: A force never acts alone. There is always another force acting at the same time, in the opposite direction. The two forces act as a pair, on two different things.







SOME THINGS TO TRY

Bend two paper clips to form hooks. Tape one to the edge of your desk. Tape the other to a block of wood.

Then hook the two paper clips together. Let them hold up the block. Which way does each of the paper clips pull? How do you suppose the pulls of these two paper clips compare in strength? You can find out with the help of a long, thin rubber band.

Hang the rubber band on the paper clip taped to the desk. Hook the paper clip taped to the block on its other end. Then let the block down slowly until the rubber band holds it up.

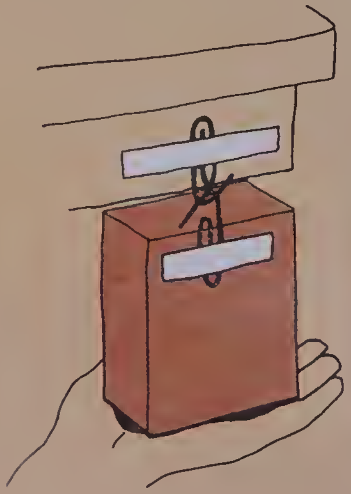
Now the paper clip taped to the block pulls downward on the rubber band. How hard does it pull? Measure the length of the rubber band. How much has it stretched?

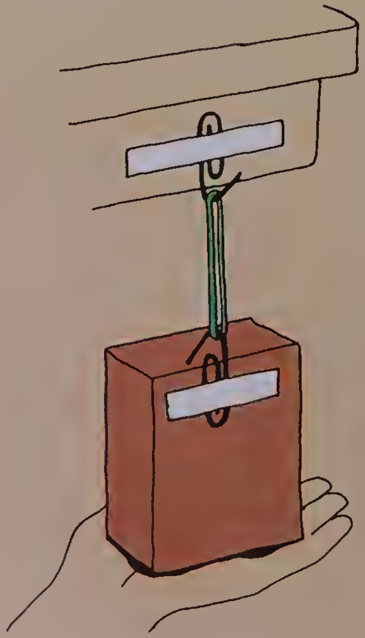
Next, take the block off the rubber band and set it on the desk. Remove the paper clip from the edge of the desk and hold it. Leave the rubber band hanging on it.

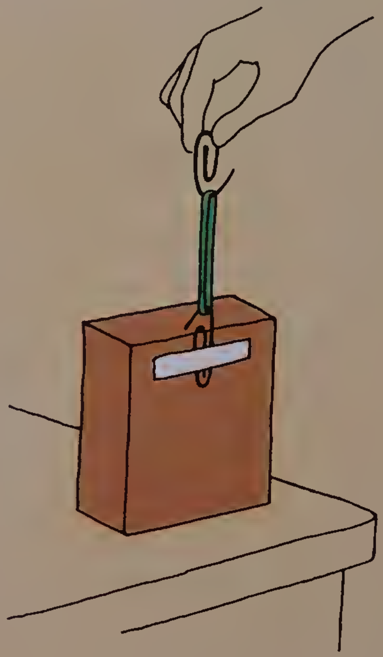
Then catch the paper clip taped to the block with the lower end of the rubber band. Pull up slowly until you lift the block off the desk a little way.

Now the paper clip in your hand pulls upward on the rubber band. How hard does it pull? Again, ask someone to measure the length of the rubber band. How much has it stretched?

You now have compared two pulls. Was either of them stronger than the other? Or were they equal? How can you tell?







Finally, take away the rubber band. Hook the paper clip held in your hand on the one taped to the block. Then lift the block off the desk.

Now which way do the paper clips pull on each other? How do you suppose their pulls compare? Are these pulls a pair of forces?

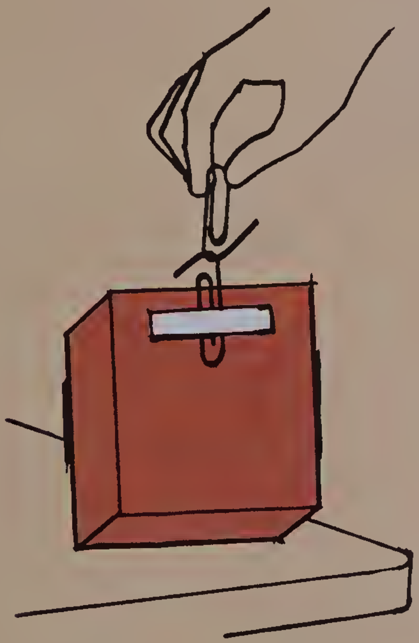
When you pull on someone, how does your pull compare with the other person's pull?

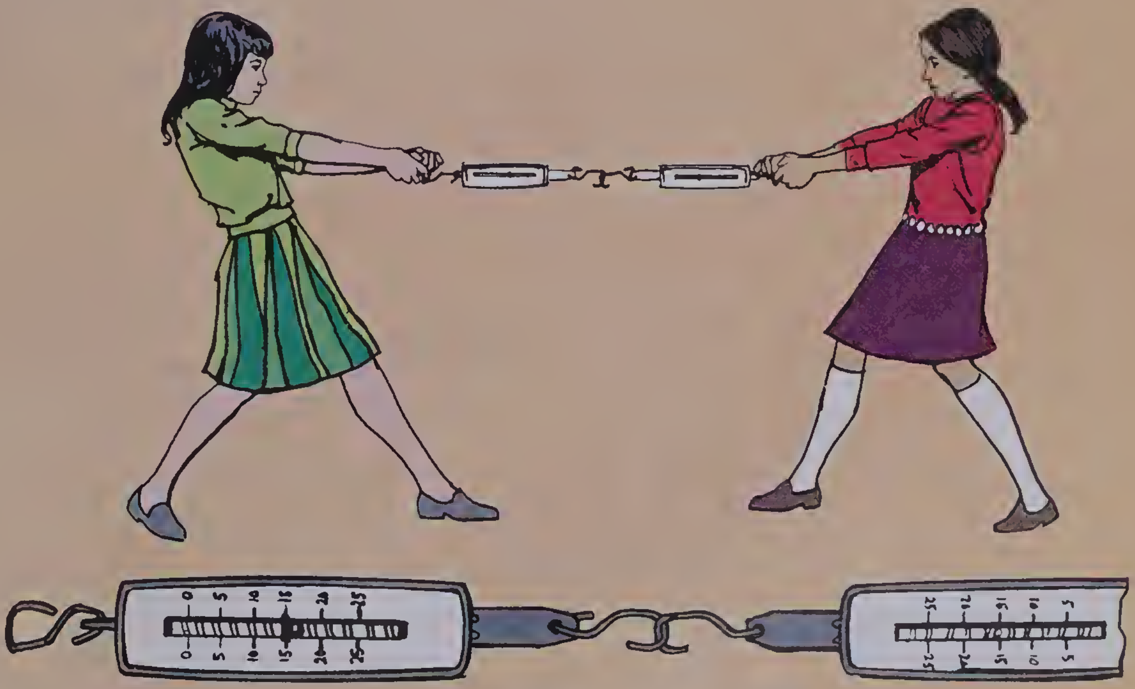
Measure your pulls with two similar spring scales. First check the scales to be sure that they read the same when different objects are weighed with them.

Hold one and have a partner hold the other. Hook them together. Then pull steadily in opposite directions. Be sure to hold the scales in line with each other. Then ask two other persons to read the scales at the same time.

Do the scales show the same or different amounts of force? Are you able to make your scale read higher or lower than your partner's?

How, then, does your pull compare with your partner's pull? Does it make any difference how hard or how easily you pull?



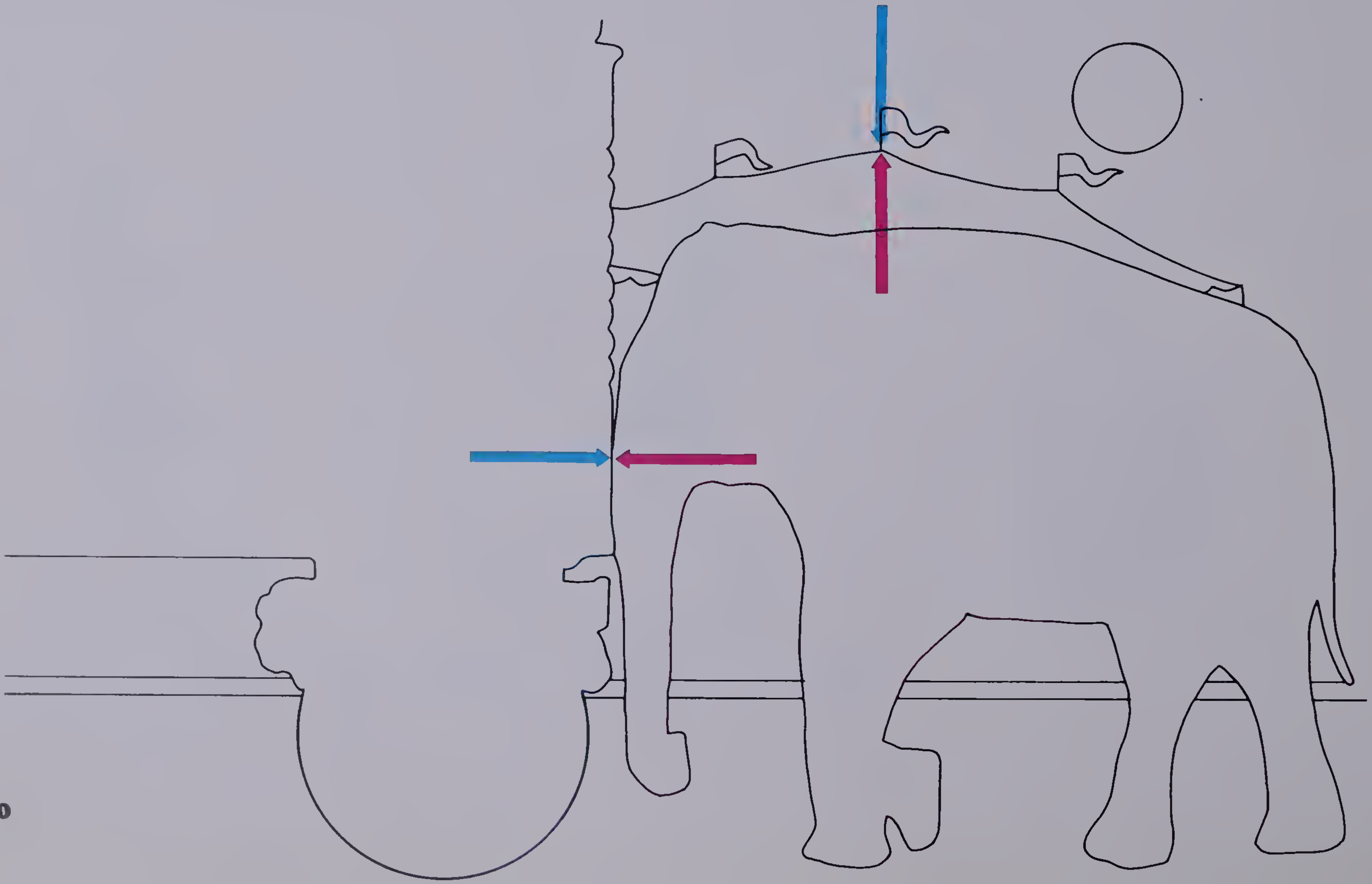


Things that interact. Here is the same drawing you saw before. But it doesn't show forces as though they were single. Instead, it shows them acting in pairs. Vectors of different colors stand for each pair of forces.

The two forces of a pair are equal and opposite. And they act on two different things. The two things also act on each other. Things that act on each other *interact*.

For example, the elephant and wagon interact. The elephant pushes against the wagon. The wagon pushes against the elephant—just as hard. Also, the workers pull on the tent rope, and the rope pulls equally hard on the workers.

Whenever one thing pushes or pulls on another, the second thing pushes or pulls on the first. The two things exert forces of equal strength on each other, in opposite directions.

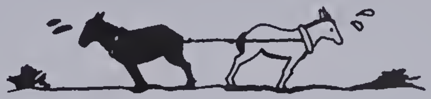


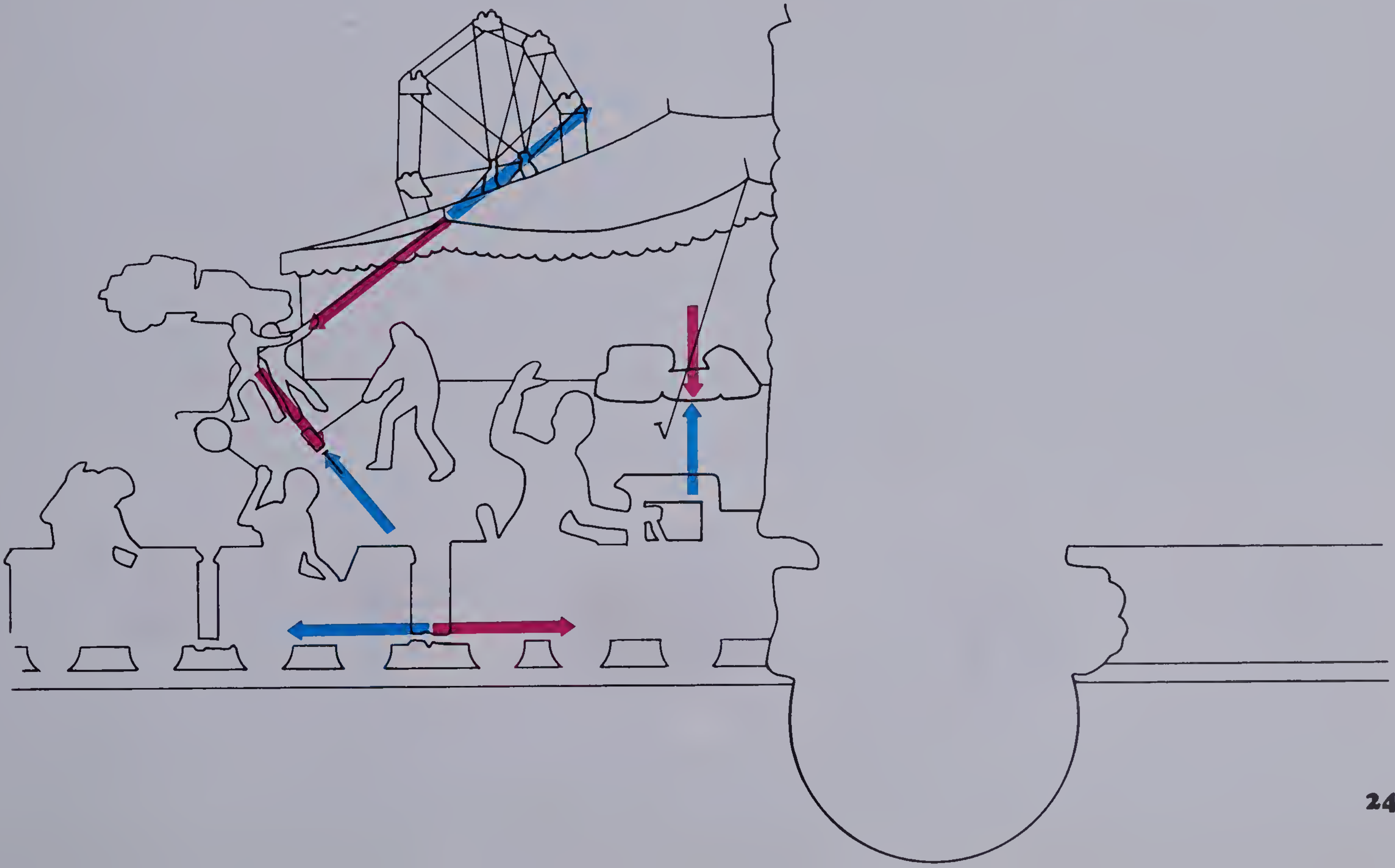
When things interact, it makes no difference whether or not they are moving. There is always a pair of forces—equal and opposite—acting between them. It makes no difference whether or not the forces cause changes in the things or their motions. There is still a pair of forces acting between them.

SOME THINGS TO THINK ABOUT

1. Which of the forces that you find in the drawing seem to be causing changes in the motions of things? What sorts of changes in motions may these forces be causing?

2. Strange as it may seem, these two donkeys are pulling equally hard on each other. This is true no matter which one wins! Then how is it possible for one of the donkeys to win?





Pairs of forces as things move ahead. When something pushes or pulls on something else, there is always a pair of forces between them. This is true even when one of the things is moving in relation to the other.

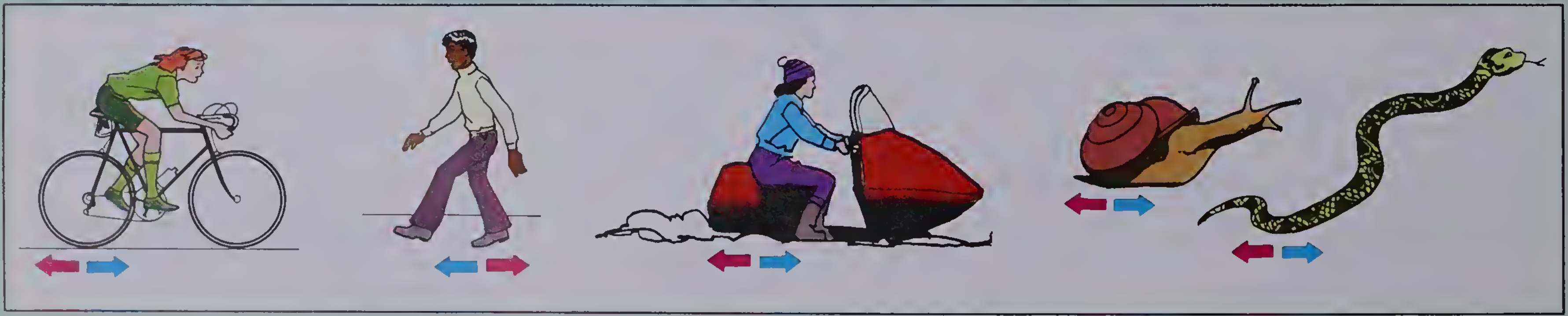
For example, when you ride a bicycle, it moves in relation to the pavement. To go forward, you make its rear wheel push backward against the pavement. At the same time, the pavement pushes forward against the wheel. There is a pair of forces acting between the wheel and the pavement. Both forces of the pair are equal and opposite to each other.

The forward force that the pavement exerts on the wheel keeps the bicycle going. This happens even though friction tends to make it stop. In fact, if this forward force is great enough, it may even make the bicycle speed up. At the same time, the wheel exerts a backward force. What does this tend to make the pavement do?

In a like way, when you walk or run, each foot pushes backward against the floor. At the same time, the floor pushes forward against this foot with an equal force. The forward force that the floor exerts against your foot keeps you moving ahead or makes you go faster. What does the backward force that your foot exerts make the floor do?

This is also true of snowmobiles and swamp buggies, and of snails and snakes. To keep moving forward, or speed up, these things must push backward. Then the snow or ground, or whatever else they are pushing backward against, pushes forward against them—equally hard. This forward force is what makes each of these things move ahead.

Now suppose that you make a bicycle or snowmobile slow down. Is there still pair of forces—forward and backward—acting between it and the pavement or snow? If so, does the force act on each thing? In which direction?



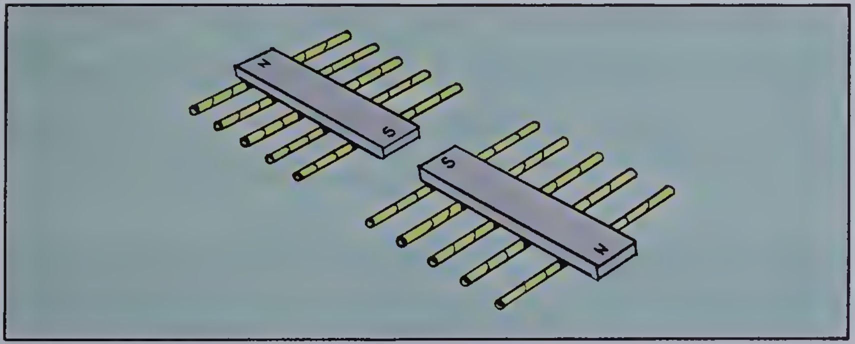
Changes in Motions LESSON 6

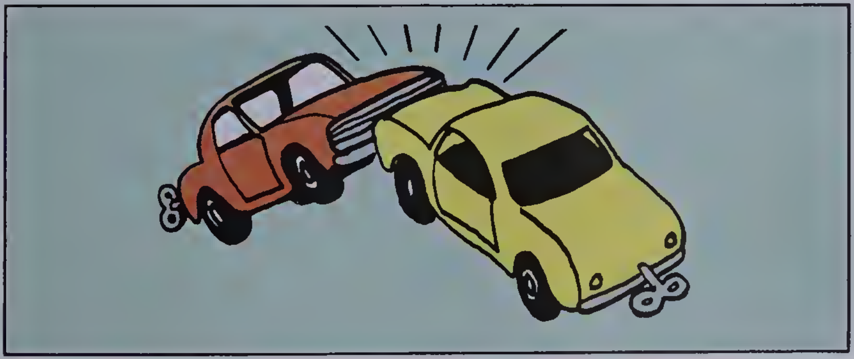
You know that forces often cause things to change their motions. They may make things

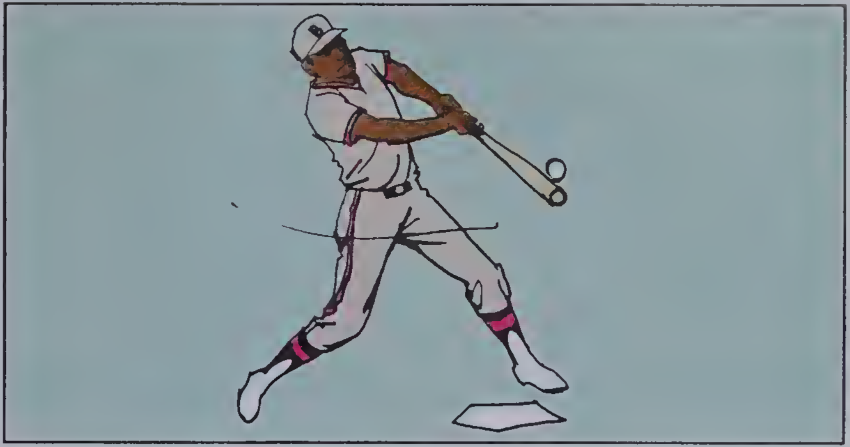
- start moving or stop
- go faster or slower
- change their direction

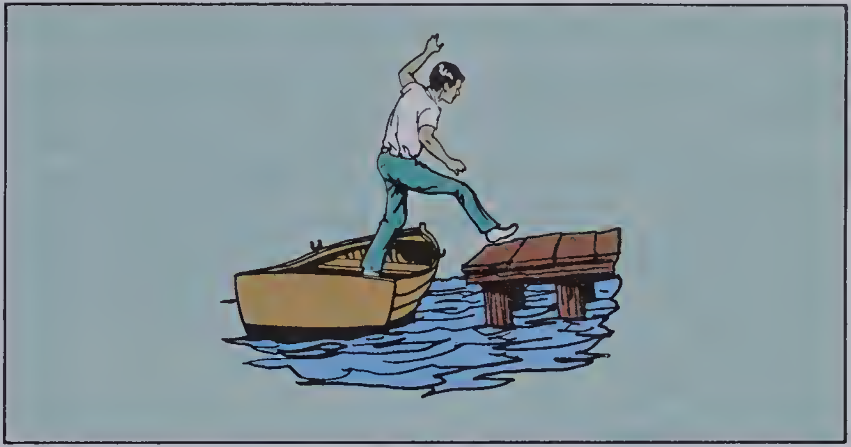
But forces always act in pairs. And the forces of a pair act on two different things. So, if the forces cause a change in motion, wouldn't they change the motions of both things?

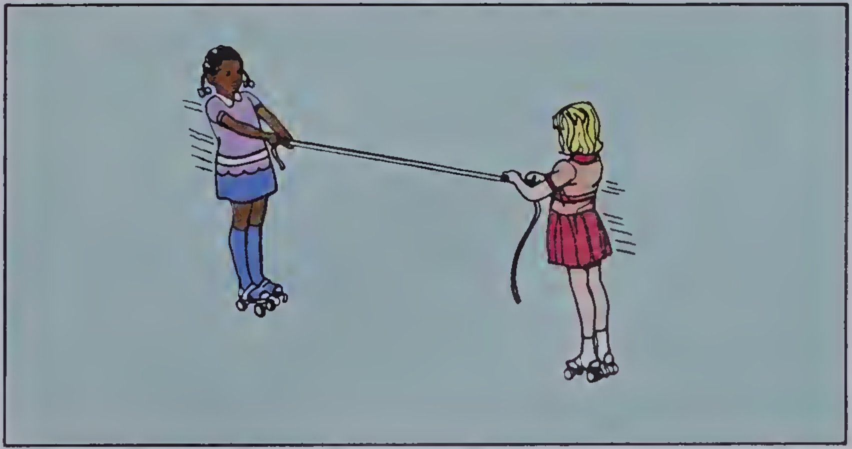
In these pictures, what changes are taking place in the motions of persons or things? In each case, what pair of forces is causing these changes in motion?











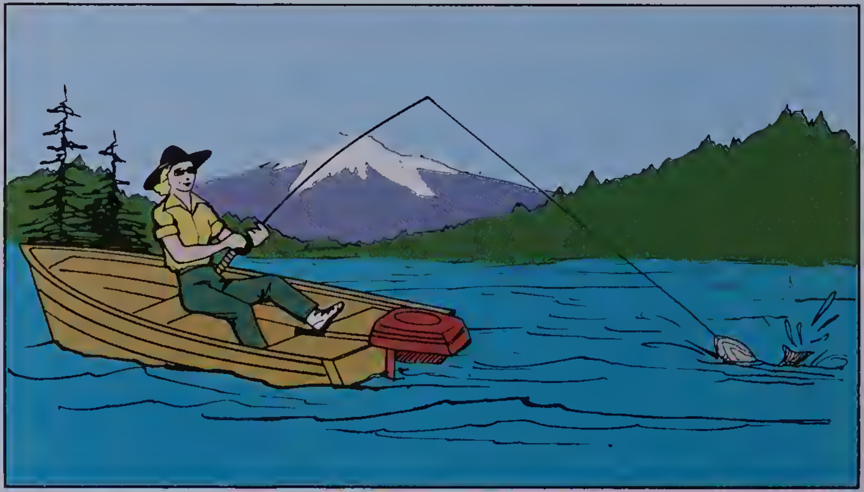
Force and change in motion. The motion of the football is being changed. In what way is it being changed? If you were the player, what would you do to make the ball's motion change greatly?

You would kick the ball as hard as you could! A strong force would cause a greater change in its motion than a weak force would. Would this also be true if you threw the football?

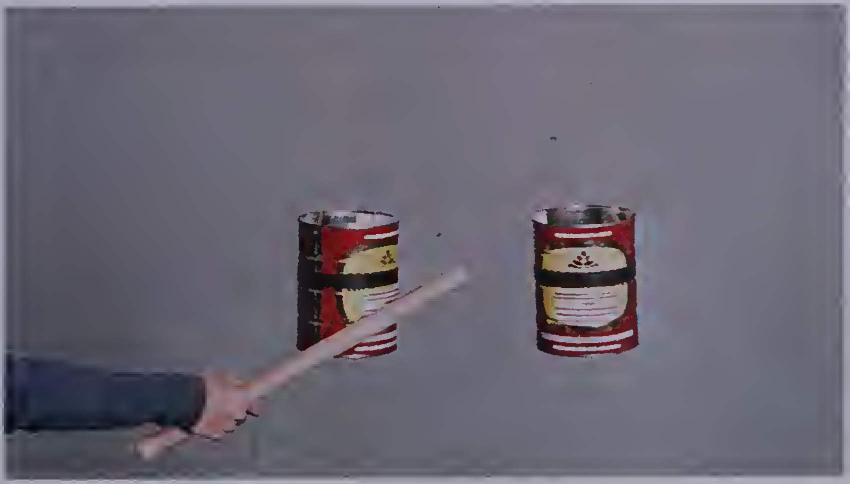
Time and change in motion. The longer a force keeps acting, the greater the change it can cause in an object's motion. This is why "follow-through" is important in games like tennis and golf. During follow-through, the racquet or club keeps touching the ball and pushing on it. The longer it pushes on the ball, the greater the change in the ball's motion.

Mass and change in motion. Two objects that interact may not have the same mass—the same amount of matter in them. Even so, the forces that they exert on each other are still equal!

However, because of the difference in mass, the motions of the objects change by different amounts. In the picture, which motion is being changed more—the fish's or the person's? Why?

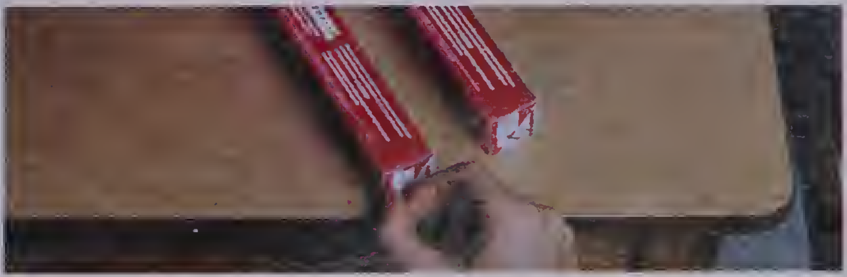


Comparing mass. It is easy to compare the mass of two objects. The usual way is to compare their weight. The more mass an object has, the harder the earth pulls on it—and the more it weighs. As you know, though, mass is not the same as weight. Mass is the amount of matter in something. Weight is a force—the amount of the earth's pull on something.



But there is another way to compare the mass of two objects. This is to have equal forces act on them for equal lengths of time. Then we can observe the changes in their motions. The object with the smaller mass will show the greater change in motion. And the object with the greater mass will show the small changes in motion.

For example, how can someone tell, without looking, which can in the left picture is filled with sand and which is "empty"? In the picture below, how can someone tell which box has toothpaste in it, and which has only air in it?



SOME THINGS TO TRY

1. What effect does mass have on changes in motion?

Find two shoe boxes that are just alike. Then cut a rubber band to make a long strip of rubber. Tape one end of this strip firmly to one end of each box.

Now set the boxes on drinking straws, for rollers. Pull them apart so that the rubber stretches. Then let both boxes go at the same time.

In what ways are the motions of the boxes changed? What forces cause their motions to change? How do their changes in motion compare?

Next, stick a large lump of modeling clay firmly to the bottom of one box. Or else tape a wooden block to its bottom. Again pull the boxes apart and let them go at the same time.

This time, how do their changes in motion of the boxes compare? What effect does the added mass of the clay or wood have on their changes in motion?

2. How do rockets and jet airplanes work?

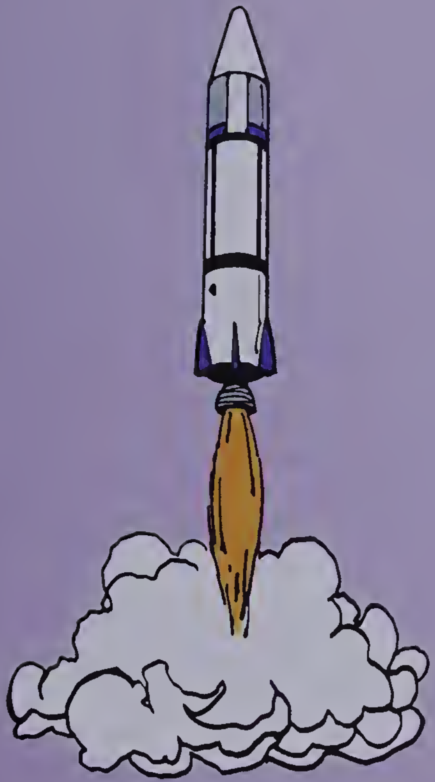
Get a lightweight cardboard box and a large balloon. Cut a round hole in one end of the box. Make the hole slightly smaller than the mouth of the balloon.

Now blow up the balloon. Hold its neck closed and put the balloon inside the box with its neck through the hole. Then set the box on drinking straws and let go.

What happens to the motion of the box as the air escapes from the balloon? What causes this?

Think of the forces exerted by the rubber of the blown-up balloon. The stretched rubber pushes on the escaping air. At the same time, it pulls on the box. And so the motions of both the air and the box are changed.

This is how rockets and jet airplanes work. Hot gases are pushed out in one direction. At the same time, the rocket is pushed in the other, with equal force.



Going places with interactions. Jet airplanes and rockets work because forces act in pairs. Jet engines and rocket engines both shoot out hot gases at high speed. In each case, there is an interaction between the gases and the engine. The gases are pushed backward. The engine is pushed forward, with equal force. The engine, in turn, pushes forward on the airplane or rocket.

In everyday life, you can see many other examples of how interactions are used to go places. When a person rows a boat, the oars are used to push backward against the water. At the same time, the water pushes forward against the oars, equally hard. The oars carry the forces between the person and the water. The water moves one way, and the person, together with the boat, moves the other.

Even when you walk or run or ride a bicycle, interactions make your motion possible. In each case there is a pair of forces acting. The forward force makes you or the bicycle move ahead, and perhaps even speed up. The backward force tends to make the sidewalk or road move backward. However, the sidewalk or road is firmly fastened to the earth. And so, the backward force tends to make the whole earth move the other way!

Ideas for REVIEW

- Pushes and pulls are forces, and their direction and strength may be shown by vectors.
- Forces often cause changes in the motion of things, making them start moving, speed up, slow down, stop, or change directions.

- Forces also may cause changes in the shapes or sizes of things by squeezing, stretching, bending, or breaking them.
- Things have weight because of the pull of the earth, known as the force of gravity.
- Something may exert more than one force at the same time, in different directions.
- Objects often transmit forces, and the stronger the object is, the greater the forces it can transmit.
- Forces act in pairs, and the forces of a pair act with equal strength on two separate things, in opposite directions.
- Because the forces of a pair act on two separate things, they tend to change the motions of both things.
- The stronger a force is, the more of a change it can cause in the motion of whatever it acts on.
- The longer a force acts, the more of a change it can cause in the motion of whatever it acts on.
- The less mass a thing has, the more of a change a force can cause in its motion.
- Pairs of forces make it possible to walk, run, or ride a bicycle. They make it possible for cars, boats, or airplanes to move.

TEST Your Understanding

Write the numbers 1-15 on a piece of paper. Use the words from the following list to fill in the blanks. Each word is used only once. *Do not write in this book.*

acting
bent
broken
direction
faster
forces
move
moving
motions
push
pull
slower
squeezed
stretched
stop

Whenever something starts to **1.** _____ , it is because a **2.** _____ or a **3.** _____ is acting on it.

Whenever things go **4.** _____ or **5.** _____ or **6.** _____ this is because of forces acting on them.

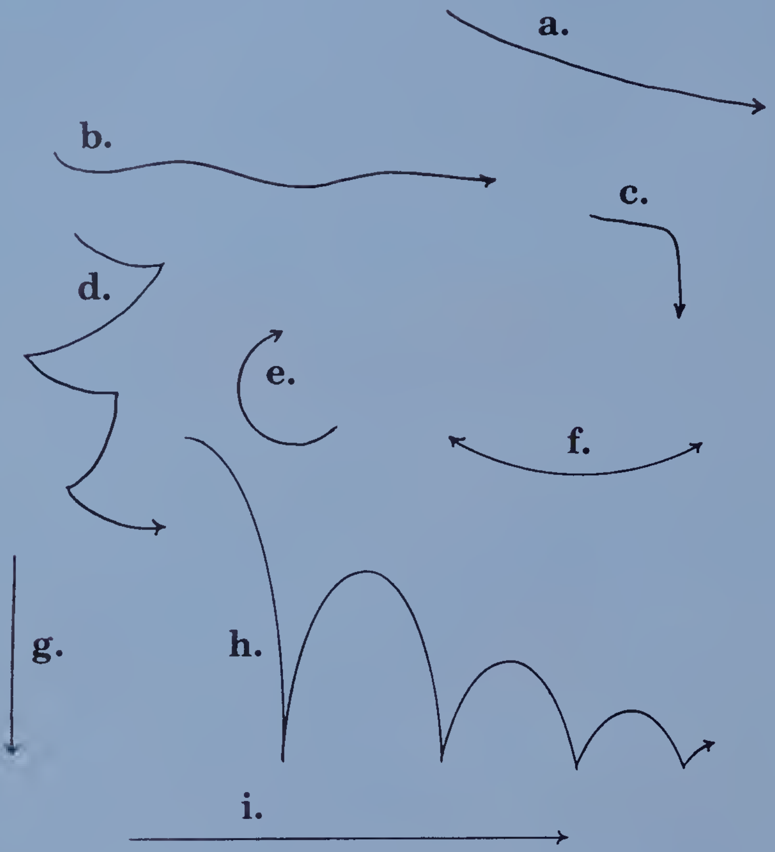
Whenever moving things change the **7.** _____ of their motion, it is because of **8.** _____ acting on them.

Whenever things are being **9.** _____, **10.** _____ , **11.** _____ , or **12.** _____ , it is because forces are **13.** _____ on them.

But many forces act on things that are not moving and also on things that are **14.** _____ without causing any changes in them or in their **15.** _____ .

PROBLEMS

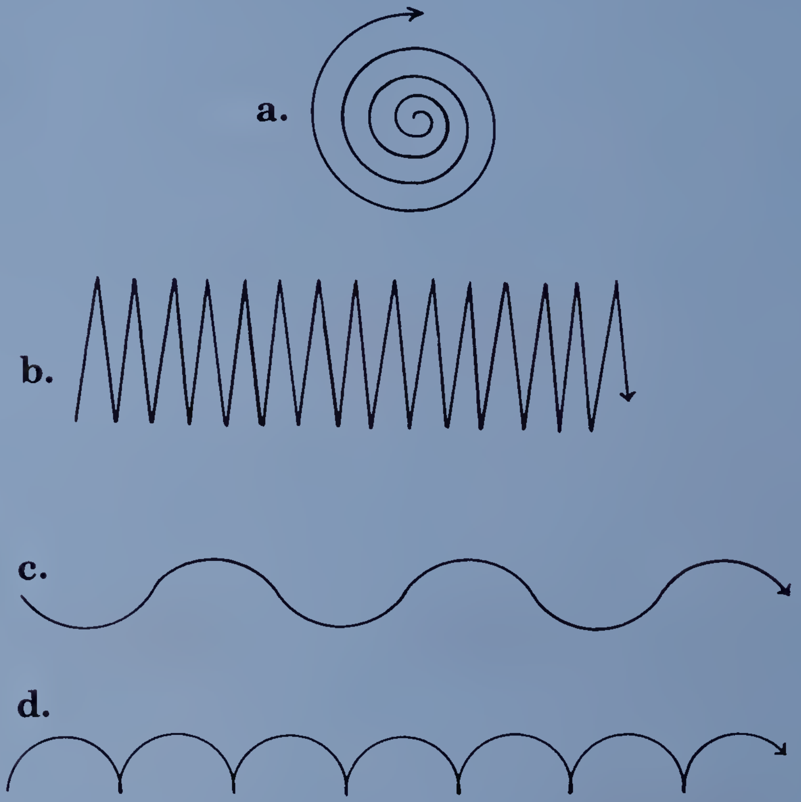
1. These lines represent the paths of moving objects.



Here is a list of objects. Now can you tell which object made which path?

1. airplane landing
2. automobile turning
3. ball bouncing
4. drop dripping
5. finger dialing
6. goldfinch flying
7. leaf falling
8. pendulum swinging
9. puck sliding

2. Now can you guess what moving objects may have made paths like these?



3. Choose any three of the paths shown. Tell which kind of change in motion takes place along each of the paths. The possible changes are these: start moving, stop moving, speed up, and slow down. Also tell where each change in motion takes place.

FIND OUT on Your Own

Bring to class a toy or game that moves—perhaps one of those shown. Show your classmates how this toy or game works. With them, observe it carefully. Can you tell

- what pairs of forces are acting, and what they act on?
- where forces are transmitted from place to place, and through what?
- what changes the forces cause in things or in their motions?

If you try to turn this toy over while it is spinning, how does it move?

How might this toy also be used to compare or measure how strong forces are?

How is this material changed by slow pushes and pulls? By very fast ones?

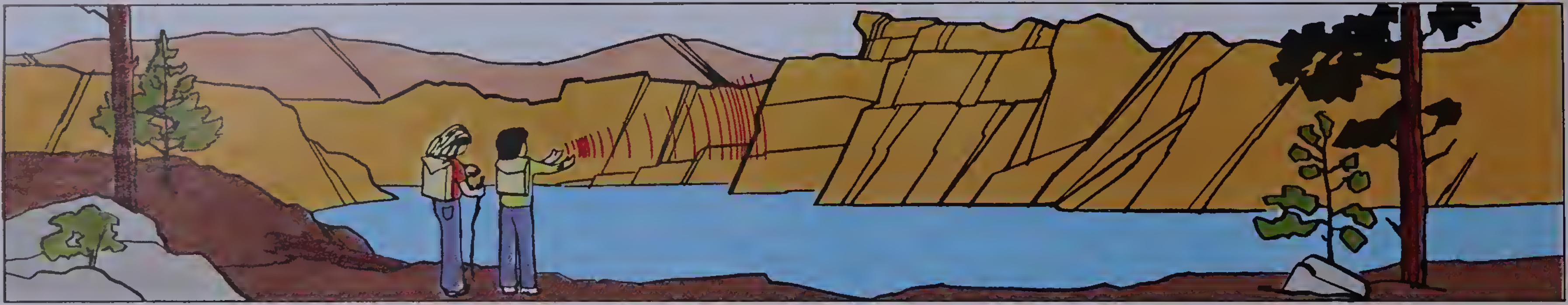
9 The Moon—Our Nearest Neighbor

Less than 15 years ago, people did something that they had never done before. During all their thousands of years on earth they were not able to do this—not until several years ago.

Then, for the first time, people left the earth and made a visit to another object in space. They went to the moon!

For many years people dreamed of going to the moon. They imagined being carried there by swans, and by balloons filled with hot air. They wrote stories about trips to the moon in flying chariots and in rockets.

But not until 1969 was it possible for people to get to the moon. Many years and a great deal of money were spent in doing this. Thousands of workers helped to do the job. Then, on July 20th, two astronauts, Neil Armstrong and Edwin Aldrin, stepped onto the surface of the moon. People had made their first trip to the moon.



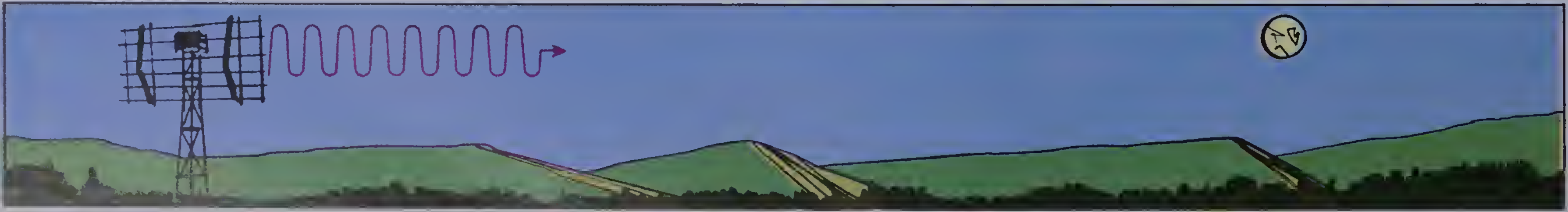
Of course, no one is able to stretch a tape measure from the earth to the moon. Still, scientists have been able to find this distance without going to the moon. They have been able to do this in two different ways.

One way. Did you ever find the distance to a cliff by timing an echo? An echo is caused when sound is reflected by something. Suppose that you stand a distance from a cliff and clap your hands. You hear the echo 4 seconds later. How far away is the cliff?

We know that sounds in air travel about 335 m in one second. Then, in 4 seconds, the sound must travel 4 × 335 m (1340 m) in going to the cliff and back. Therefore the cliff is about 670 m away.

Scientists have timed how long it takes a radio signal sent to the moon to return to earth. A radio signal sent to the moon returns about 2.5 seconds later. Radio signals travel much faster than sound!

This means that it takes about 1.25 seconds for the radio signal to go to the moon. And it takes another 1.25 seconds to get back. A radio signal in space travels about 300 000 km in 1 second. In .25 seconds, the signal travels 75 000 km. Therefore, how far does a radio signal travel in 1.25 seconds? About how far away is the moon?



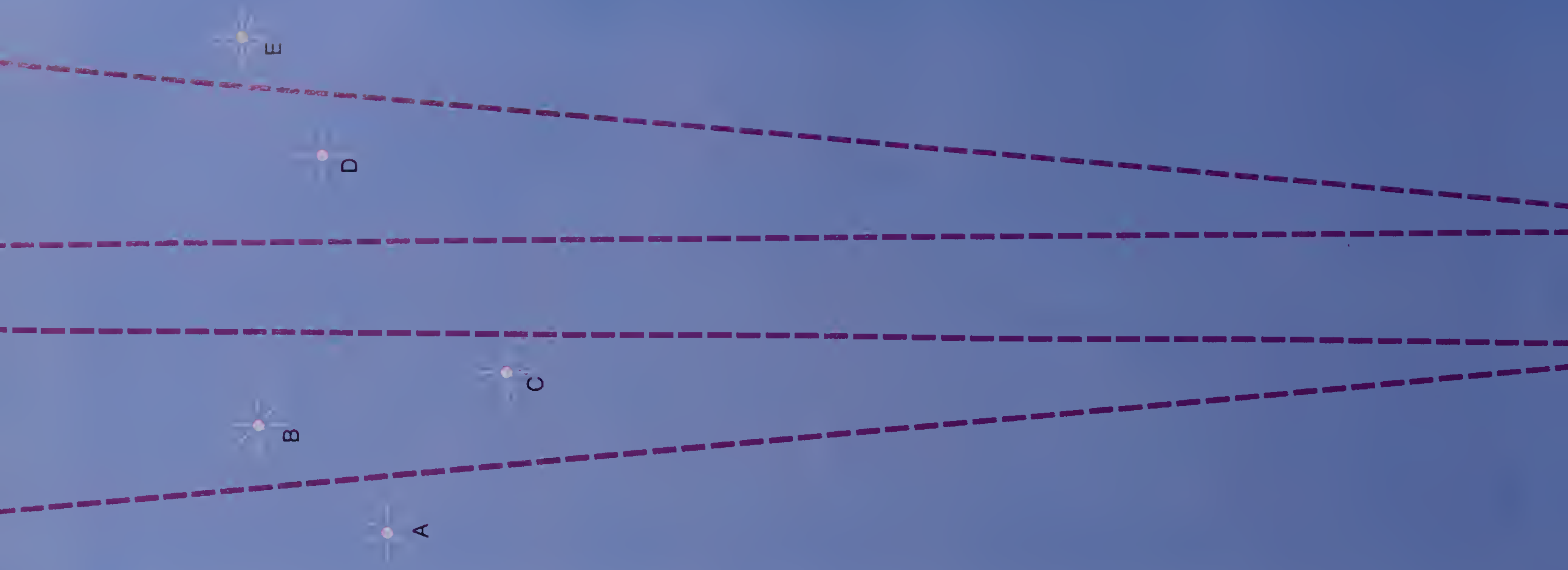
A second way. Here is another way of finding the distance to the moon. It is based on something else you may have observed. You have probably walked outside or ridden in a car at night. As you moved along, what did you notice about the moon? Did it seem to follow you?

At the same time, street lights and lights in houses seem to move past you. These lights were really standing still. But they appeared to move opposite to the way you were going. Some seemed to go past you faster than others. Which seemed to go by faster? Was it the nearer lights or the more distant ones? Which seemed to move more?

Estimating distance. The nearer that lights are, the faster they seem to pass you by. Lights that are very far away appear to move very little. In fact, they appear to keep up with you almost as well as the moon.

In this way you can estimate the distance of lights as you ride along at night. Simply notice how fast they appear to go by or how far they seem to move!

The moon seems to keep going along with you. It does this better than any objects on the earth. It seems to do this because it is farther away from you than anything on the earth.

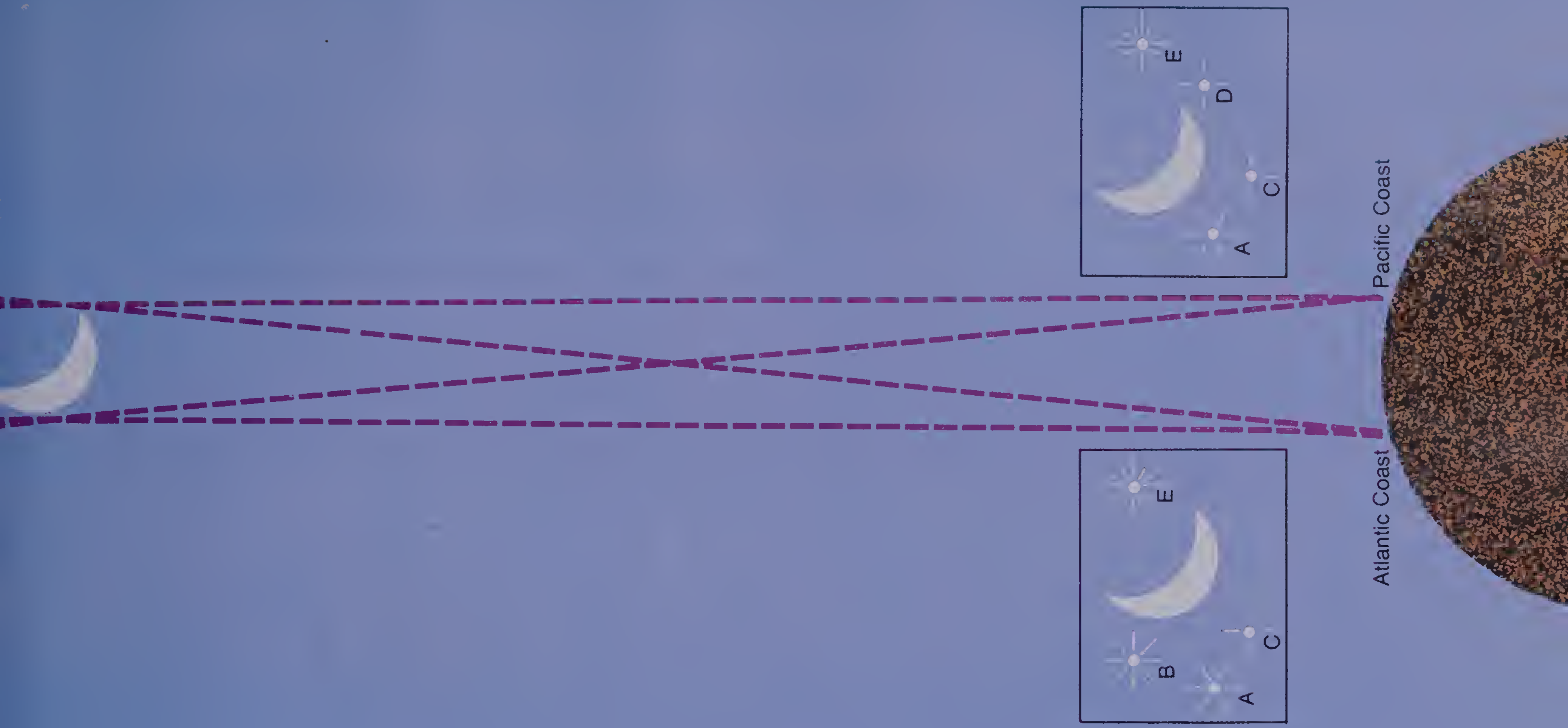


SOMETHING TO TRY

Attach a piece of tape at eye level to a window in your classroom. Move away from the window 2 m. Close one eye while you look out the window at a distant pole, tree, or building. Move your head from side to side. Notice how the tape appears to move in relation to the pole, tree, or building.

Try this again, with one difference. Hold your thumb up at arm's length, between you and the tape. Which appears to move more, the tape or your thumb? Which appears to move faster, the tape or your thumb?

Finding the distance to the moon. Using a way like this, we can find the distance to the moon and other objects in the sky. For example, suppose that you are flying in a very fast jet over a long distance. It is nighttime, and the moon is shining. Then the moon would appear to move in the opposite direction to the way you are going. Because of your motion it would seem to move slightly in relation to the stars. This would show that it is closer than the stars.



Astronomers can find out how far it is to the moon in this way. But they do not have to speed from one place to another. Instead, two of them who are thousands of kilometres apart work together. They each take a picture showing the moon and the stars near it. They do this on the same night, at exactly the same moment.

Then they look at the position of the moon in relation to the stars on each of the pictures. The stars are the same, but there is a little difference in the moon's position.

The astronomers find out exactly how far apart they are from each other. Then, they measure the difference in the moon's position, as seen from these two places.

Using these two measurements, they can find the distance to the moon. It turns out to be about 375 000 km!

SOMETHING TO DO

It is about 375 000 km to the moon. This distance is about as far as 9.5 trips around the earth! You can get a better idea of how far this is. To do this, make a small-scale model of the earth and moon.

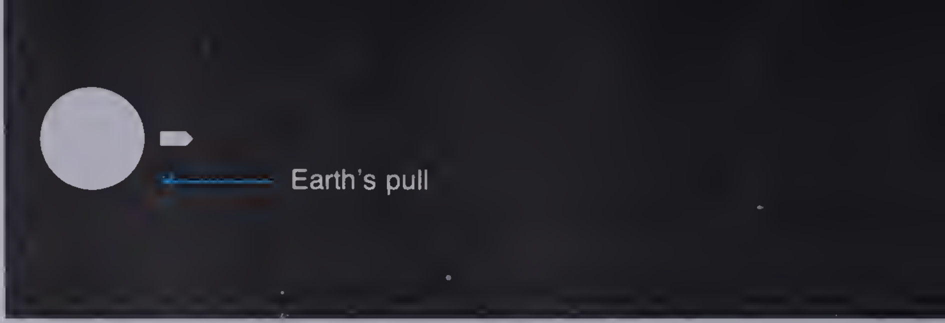
Wind a long string around the equator of a classroom globe. Cut it off when it has gone around 9.5 times. Then hold one end of the string on the globe while someone else pulls its other end. The string's length shows the moon's distance if the earth were as small as the globe!

On the same scale, how large would the moon be?

Ask someone to hold a ball at the far end of the stretched out string. Then look at the ball from your end of the string. Does it appear to be about the same size as the full moon in the sky?

If not, try balls of different sizes. Find one that looks about as big as the full moon in the sky. How could you make sure that it appears to be the size of the full moon?

Here is another way to check the size of the ball. Cut a piece of string to fit around the globe exactly once. Fold it into four equal parts. Cut off one of these parts. If your "moon ball" is the right size, this piece of string will nearly fit around it.

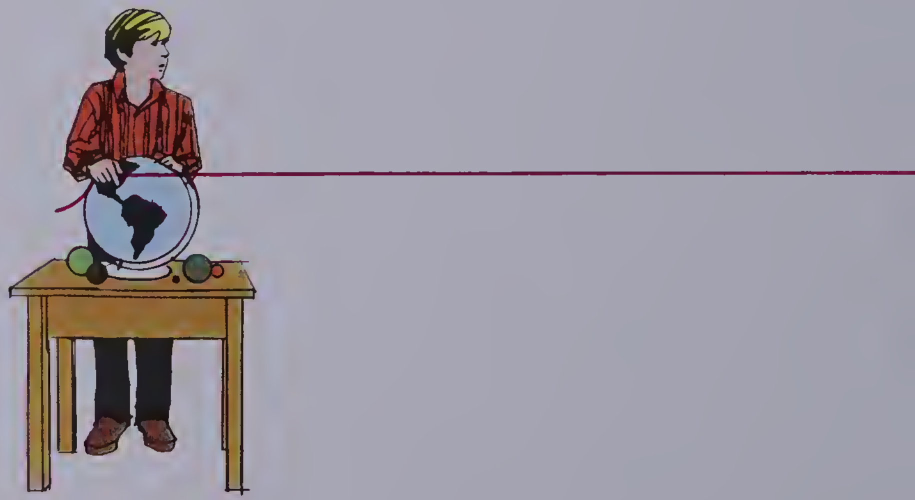


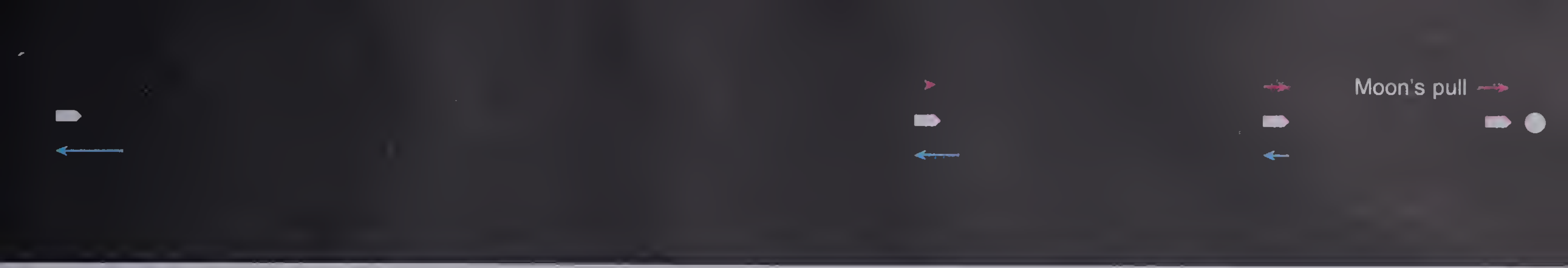
How Can People Travel to the Moon?

LESSON 2

When you throw a ball straight up, it comes down again, of course. The harder you throw it, the higher it goes. But it still comes back down. Why does it do this?

The earth pulls on a ball with a force called gravity. This pull acts on the ball even before you throw it. It keeps acting as the ball goes up and as the ball comes down. Gravity makes the ball go slower and slower on the way up. It finally makes the ball stop. Then it causes the ball to fall back down, faster and faster.





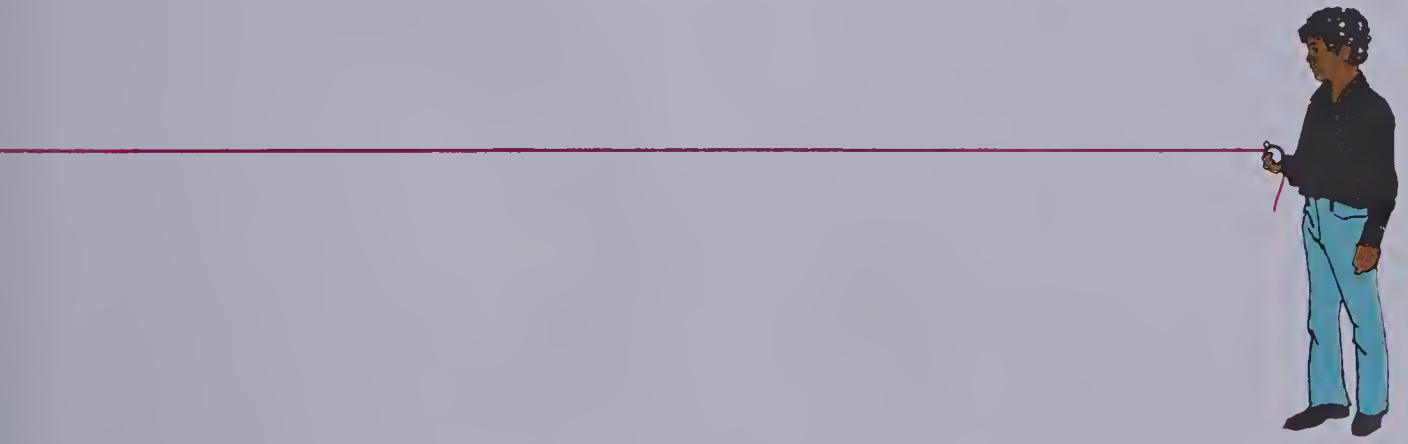
Suppose you threw a ball straight up very hard. Could you make it reach the moon? Remember, the moon is about 375 000 km up! How do you suppose you might get enough force to do this?

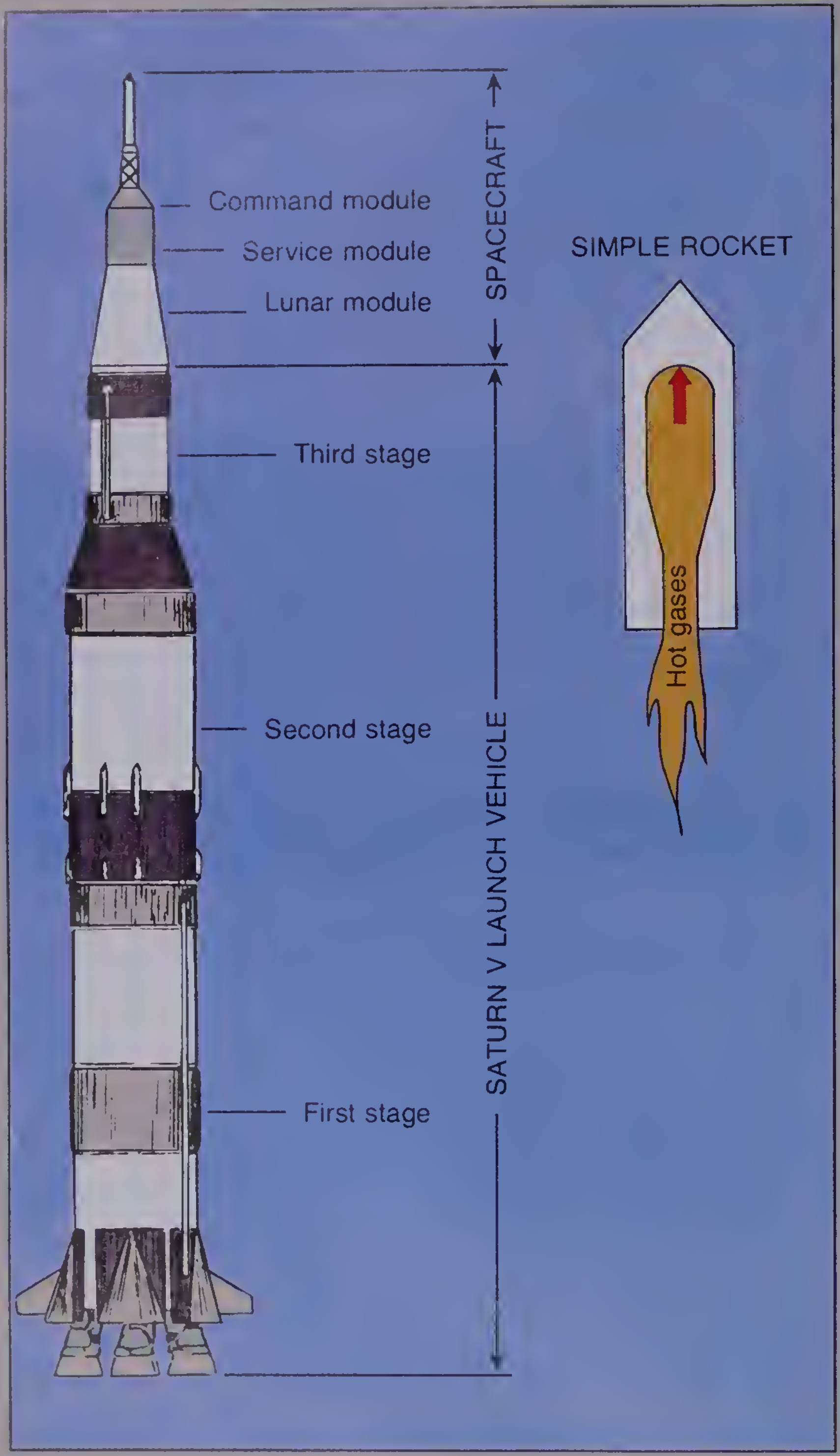
Getting an object to the moon. It would take a very great push to get an object up to the moon. However, these three things would help:

1. The earth's *atmosphere*—the air around the earth—becomes thinner with height. Higher than about 500 km, there is almost no air in the object's way. Once above this, an object is no longer slowed by air.

2. Little by little, the earth's pull on an object becomes less as the object goes higher. The object is still slowed down as it rises. But it is not slowed down as much as when it is near the earth.

3. As an object gets close to the moon, the moon's pull on it becomes greater. It becomes even greater than the earth's pull. From there on, the moon's pull makes the object fall toward the moon.



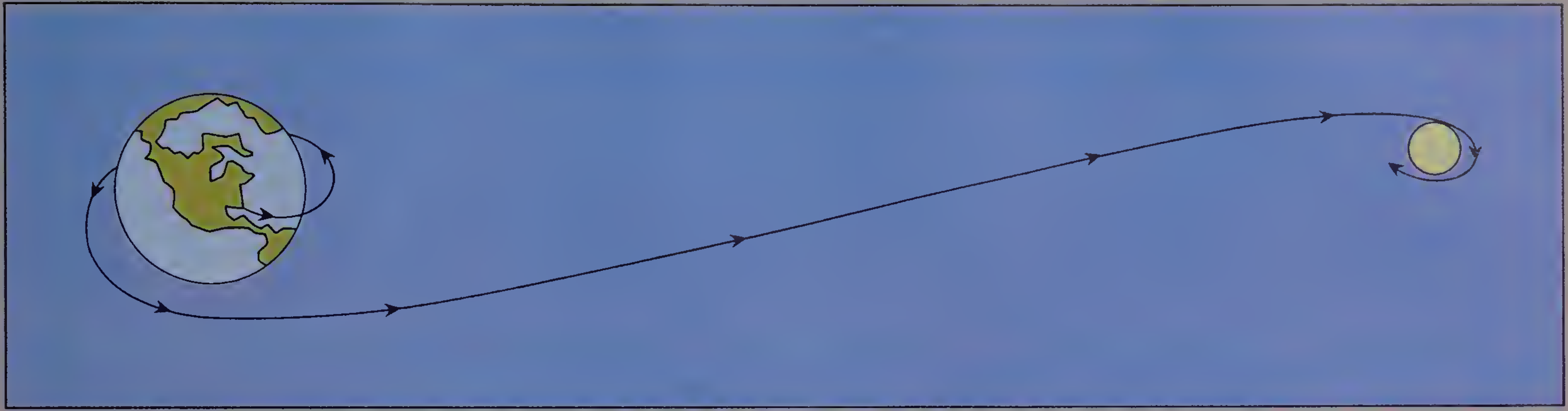


What gives the push? To get off the earth, a spacecraft must travel at high speed. Something must push on it to get it up to this speed. The push must be great. And it must act for a long time.

Today, only rocket engines are able to give the spacecraft the needed push. A rocket engine produces hot gas that shoots out very fast. There is an interaction between this gas and the engine—they push on each other equally hard. The gas goes one way. And the engine goes in the opposite direction.

SOMETHING TO TRY

Blow up a balloon and release it. Explain why it acts as it does. How does this depend on interaction?



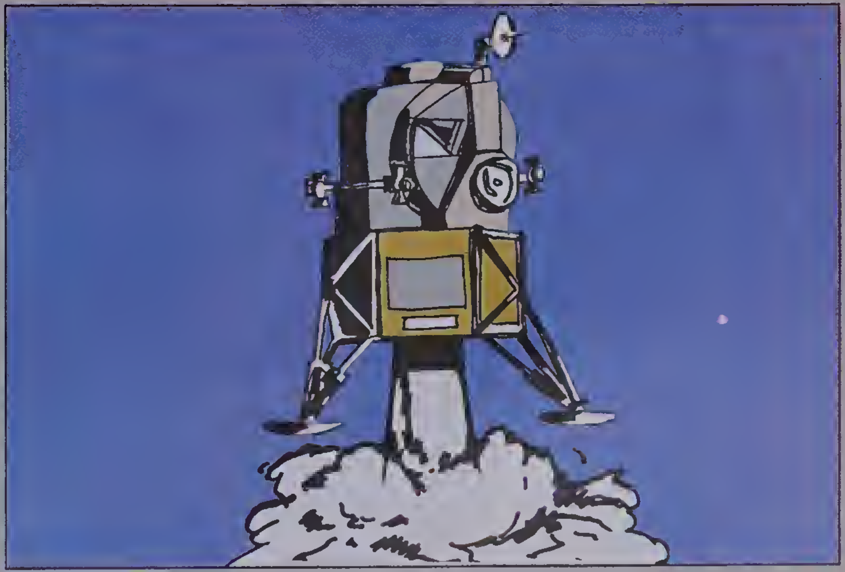
Moving in space. Once it is moving, a spacecraft needs no push to keep it going through space. There is hardly any friction on it. It has to push very little out of its way. It just keeps on going.

But pushes are needed to make any changes in the motion of the spacecraft. These pushes must also come from rocket engines. The engines can shoot out gas in different directions. And they can do this for as long as is necessary.

In this way, the spacecraft can be speeded up to take it from one path, or *orbit,* into another. For example, it may be "kicked" out of an orbit around the earth. And it may be put into one around the moon.

Also, rocket engines are used to slow down the spacecraft. For example, the spacecraft must slow down when landing on the moon. To do this, the engines are turned. The gas shoots out in the same direction as the spacecraft is traveling. Then the gas is pushed forward. As this happens, there is a backward push on the spacecraft. This push makes it slow down.

A rocket engine is also used during liftoff. It starts the spacecraft on the return trip.



Lunar module landing

The sun seems to rise in the morning. It seems to move across the sky during the day, and then set. The moon and most stars seem to do this too. They appear to keep changing their positions in relation to objects on the earth. Each day they seem to move across the sky, from east to west.

This may make you think that the sun, moon, and stars are moving. But this is not the case. Evidence shows that the apparent motion is caused instead by the *rotation,* or turning, of the earth. The earth turns in the opposite direction, from west to east.

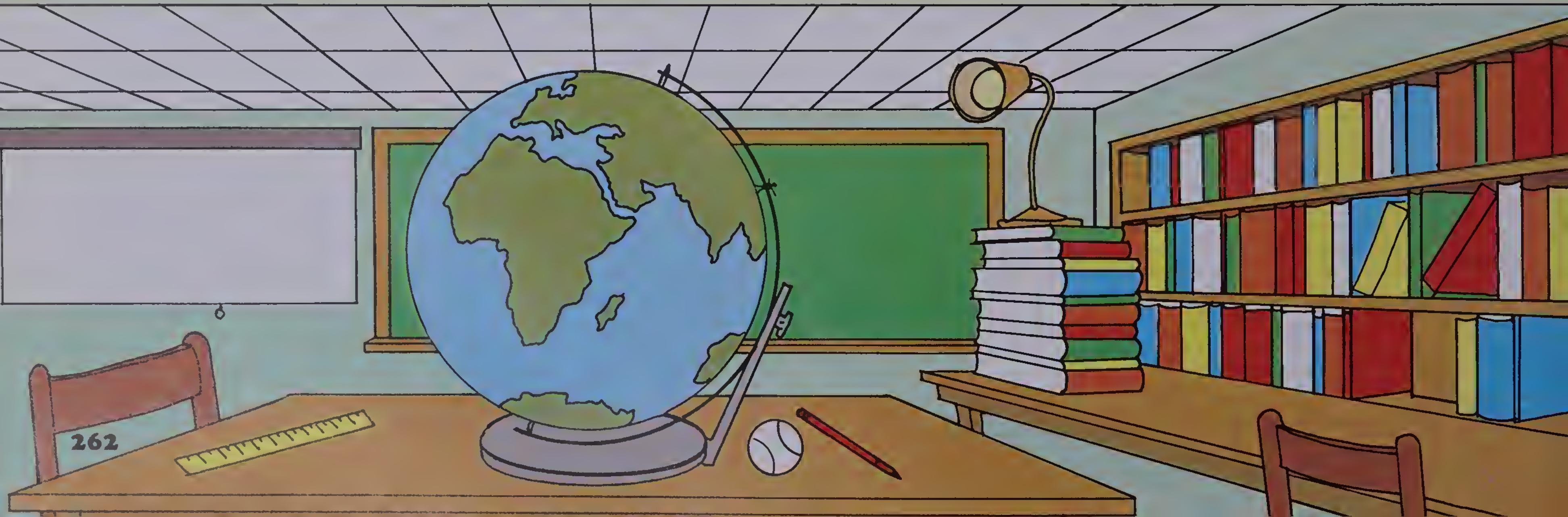
SOMETHING TO THINK ABOUT

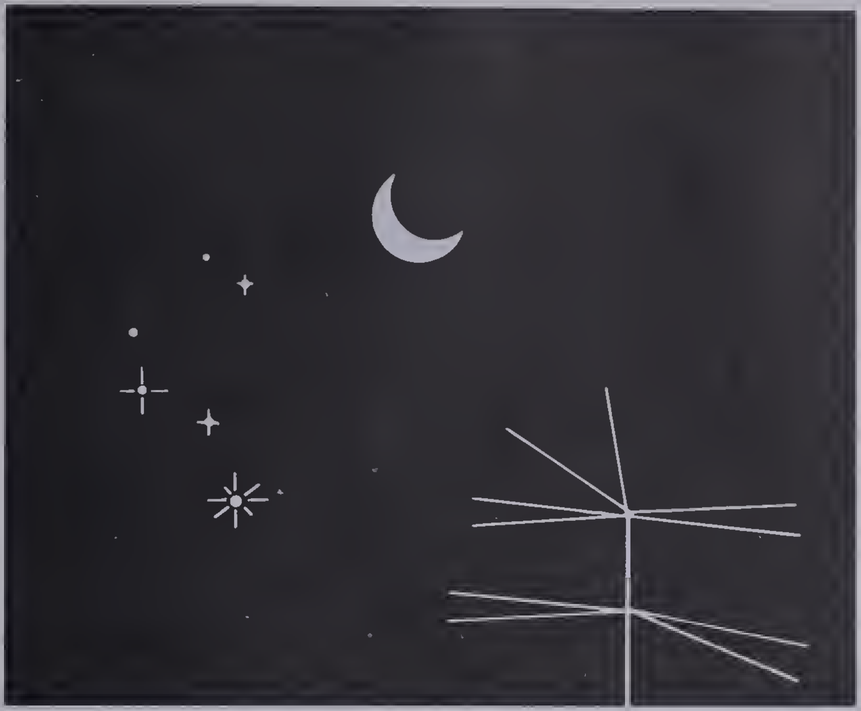
Imagine that you are very tiny, standing on a globe. Choose a spot on the globe where you would like to be. Suppose the globe were not turning. Then, which objects in the room would you *not* be able to see? Why not?

At the same time, what objects could you see from this place on the globe? These objects would appear to be in your "sky." They could stand for stars and constellations in the real sky.

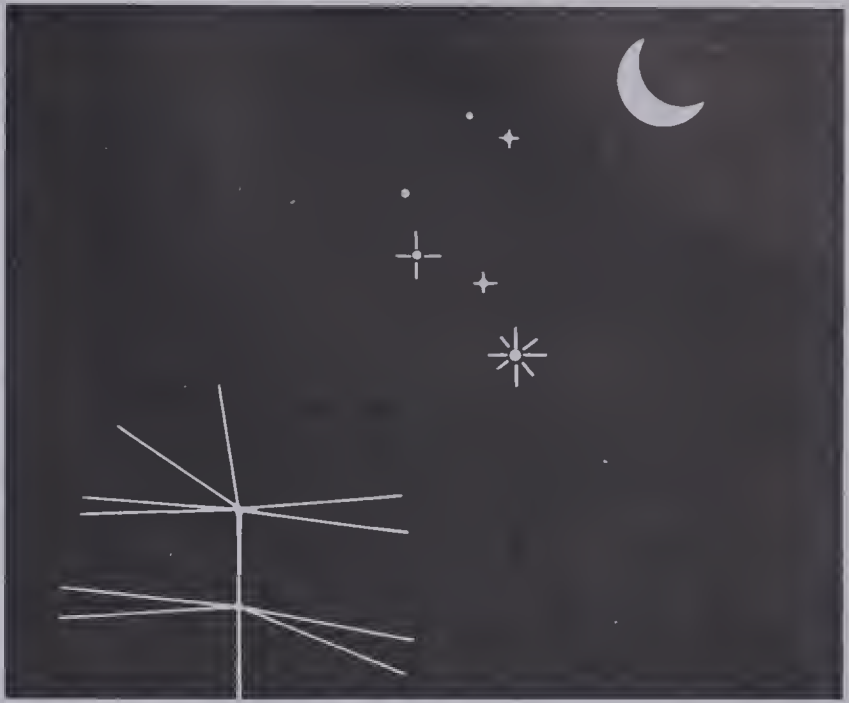
Now, suppose the globe were to turn, with you on it. What would these objects appear to do? Would they seem to rise, move across your "sky," and set—like real stars?

The globe stands for the earth. In which direction should the globe turn? Then, in which direction would the imaginary stars and constellations in your "sky" seem to move?





About 7 P.M.



3 hours later

The earth rotates once every 24 hours, from west to east. We cannot feel this rotation. Usually we do not think about it. Instead, it seems that the sun, moon, and most stars are moving, from east to west.

The moon's changing position. Several boys and girls went outdoors early one evening to look at the moon and stars.

One girl drew a picture of the moon and a few stars near it. She also showed a TV antenna on her picture. Then she marked the place where she was standing.

About 3 hours later the children checked the moon's position again. The girl stood in the same place. Then she drew another picture of the moon in relation to the stars and the TV antenna.

Now compare her two pictures. What differences do you see? During the 3 hours, what made the moon and the stars move in relation to the antenna?

During the 3 hours, did the moon appear to move in relation to the stars? If so, which way?

Where would the moon be in relation to the stars after 3 more hours? After 12 hours? After 24 hours?

SOMETHING TO OBSERVE

Watch for the moon in the sky. Try to see it in the daytime. If you do see it, note its position in relation to the sun. Point one arm straight toward the moon. Point the other arm toward the sun, but do not look directly at it. **Safety Note:** *Never look directly at the sun. You might harm your eyes.*

Now look at the angle between your arms. You might record this angle in a drawing that shows the position of your arms.

Look for the moon at night. Note its position in relation to a few nearby stars. You might draw a sketch of the moon and these stars.

The next day, if it is clear, check the moon's position again. Has it changed any in relation to the sun or stars? If so, in which direction? By how much?

Why the moon's position changes. Watch the moon for several days. Then you can see how its position changes in relation to the stars. It appears to move slowly and steadily among them, toward the east. After about 27 days it seems again to be back near the stars where it started.

Why does the moon seem to do this? It is because the moon moves, or *revolves,* around the earth. It revolves in a nearly circular orbit, from west to east. As the moon moves, its position in relation to the stars keeps changing.

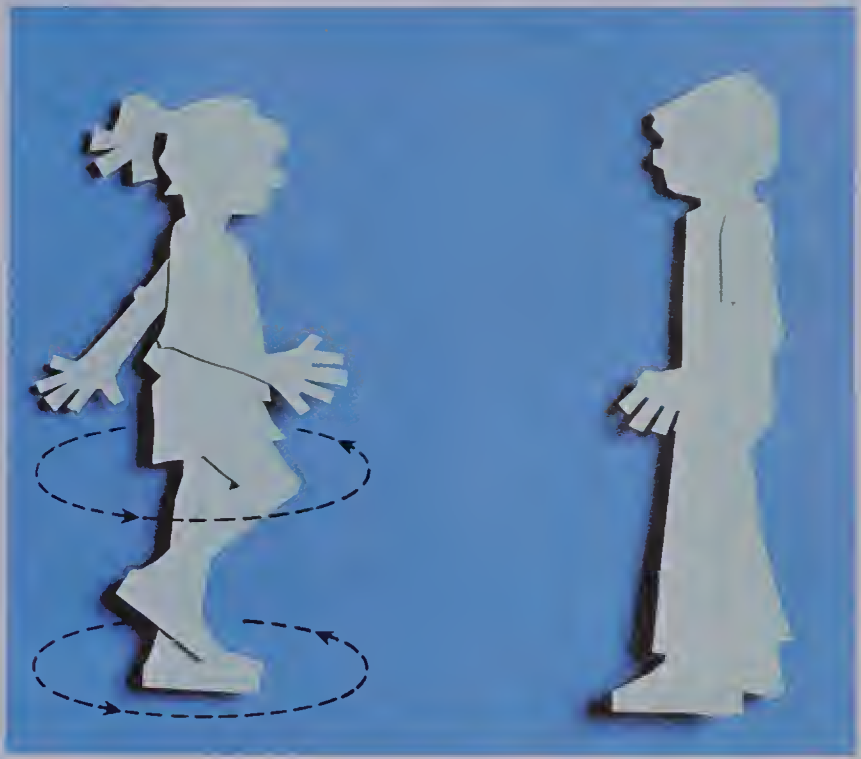
SOMETHING TO DO

Choose a partner to play this game with you. Stand facing each other, about 3 m apart. Then turn around slowly while your partner stands still. As you rotate, does your partner seem to be moving in relation to you? In which direction?

Now, while you rotate, your partner should either stand still or take a step sideways. But you shouldn't be told what your partner does. And you shouldn't see or hear your partner move. You must look straight ahead as you rotate. No peeking!

After you have turned around once, can you tell whether your partner stood still or took a step? If your partner took a step, was it toward your partner's left, or right? Was it a big step or a tiny step? How are you able to tell?

Take turns doing this. You may wish to keep score.



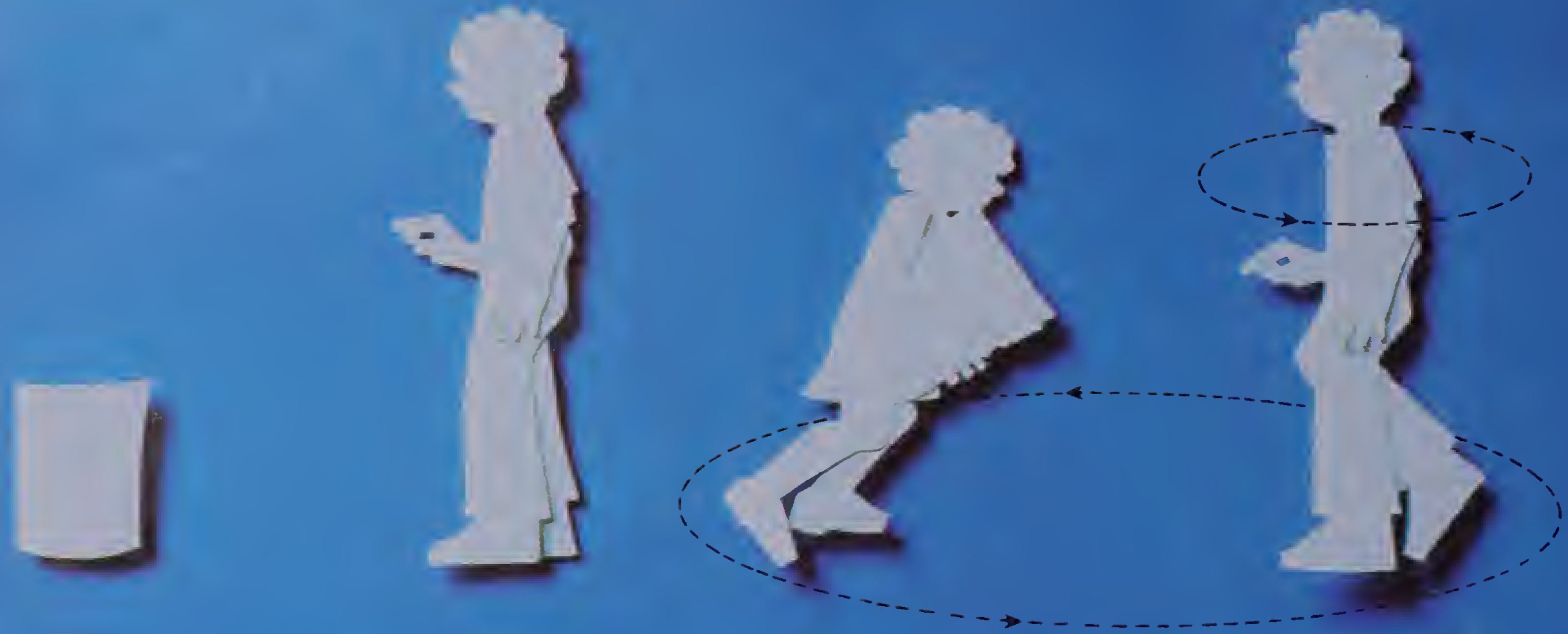
Earth motion and moon motion. It would be easier to see the moon's motion if the earth were not rotating. Even so, this isn't hard to do.

It is like being able to tell that your partner took a step sideways while your back was turned. Remember what happened when you did this. You simply saw that your partner moved in relation to objects around the room. You knew that tables, desks, and pictures didn't move.

The change in the moon's position in the sky is caused by two motions:

1. The earth rotates from west to east, once every day. This motion makes the moon, sun, and stars appear to move westward.

2. The moon revolves around the earth from west to east, once in about a month. This makes the moon appear to move eastward in relation to the sun and stars.



Aiming a spacecraft. Suppose you stood still and held a marble like this. Could you shoot it into a wastebasket? You probably couldn't miss!

But suppose you kept turning around while you shot the marble. Could you get it into the basket as easily as before? When would you have to shoot it? Would it be a good idea to wait until you were facing the basket?

Now suppose you kept rotating while someone walked around you with the basket. The person carried it in the same direction as you were turning, but much more slowly. What two motions would make it hard for you to get the marble into the basket?

We have the same problems when we send a spacecraft to the moon. We must plan for the rotation of the earth. We also must plan for the revolution of the moon.

Because of the earth's rotation, the rocket must blast off before it points directly at the moon. And because of the moon's revolution, the spacecraft must be aimed ahead of where the moon is.

Both of these things must be done accurately. Only then will the spacecraft get to where the moon will be when the moon gets there!

JOBS Using Science

As you might guess, many problems had to be solved before spacecrafts went to the moon. Some of the problems were caused by the movements of the earth and the moon.

The launching time of a spacecraft and the position of the moon when the spacecraft was to arrive had to be figured correctly. If a mistake had been made, the spacecraft would not have reached the moon.

The skills of many different people were needed to send spacecrafts to the moon. *Mathematicians* worked with computers so that times and distances were figured correctly. *Engineers* designed the spacecrafts that landed on the moon. Skilled people built the spacecrafts, the instruments in them, and the launching pad.

Astronauts traveled in the spacecrafts. They had to learn all the skills and problems of space flight. Scientists of many kinds planned how to keep the astronauts safe in space and on the moon. And these are only a few of the different kinds of workers who made landings possible.

The exploration of space has just begun. Since the landings on the moon, spacecrafts have visited the planets of Mars, Venus, and Jupiter. People did not travel in these spacecrafts. But instruments and cameras sent pictures and other information back to earth.

Where Should We Land on the Moon?

LESSON 4

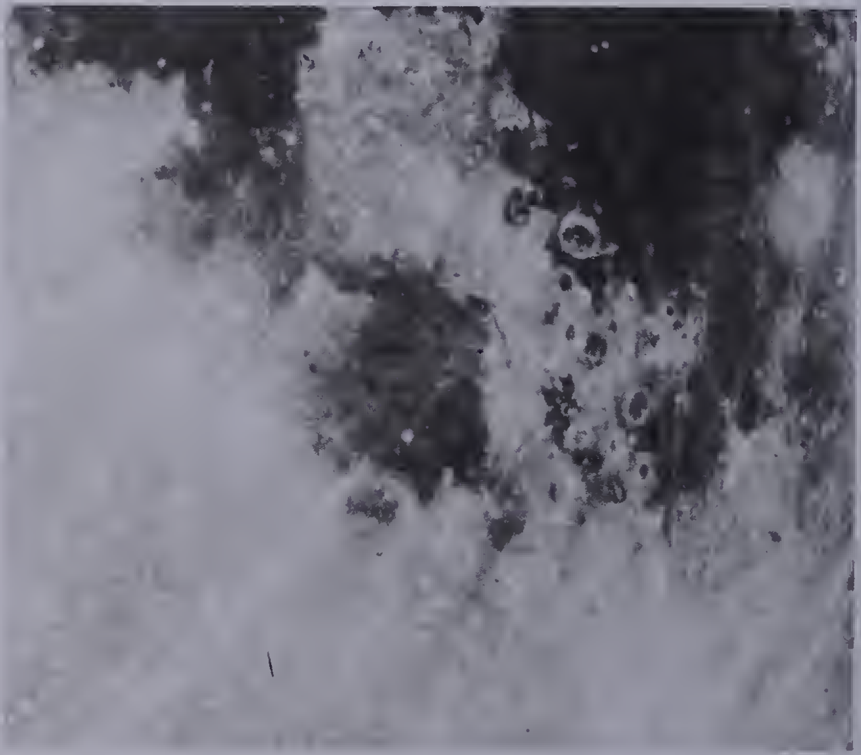
When people reached the moon, where do you think they chose to land?

First of all, they landed on the side that faces the earth. They did this so that they could communicate with the earth. They communicated by radio and television.

Radio and television signals cannot pass through the moon. They cannot go around the moon, either. They travel through space only in straight lines. In this way they act like light. Light also can't go through or around the moon.

On the side facing the earth. Did you know that the same side of the moon always faces the earth? It may not seem that way, but it does. And most of the other side stays turned away. No one has ever seen very much of the side of the moon that faces away from the earth!

However, the side of the moon that we do see looks different at different times. This happens because of the way sunlight strikes the moon. The sunlit places and shadows on the moon's surface keep changing.



SOMETHING TO TRY

Can the moon keep the same side facing the earth and still revolve around the earth?

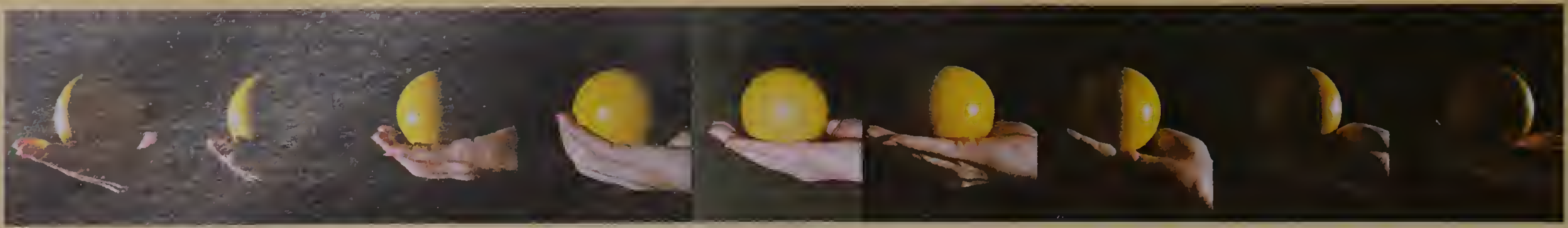
Use a ball for a model moon. Let your head stand for the earth. Hold the ball out at arm's length. Then make it turn around your head.

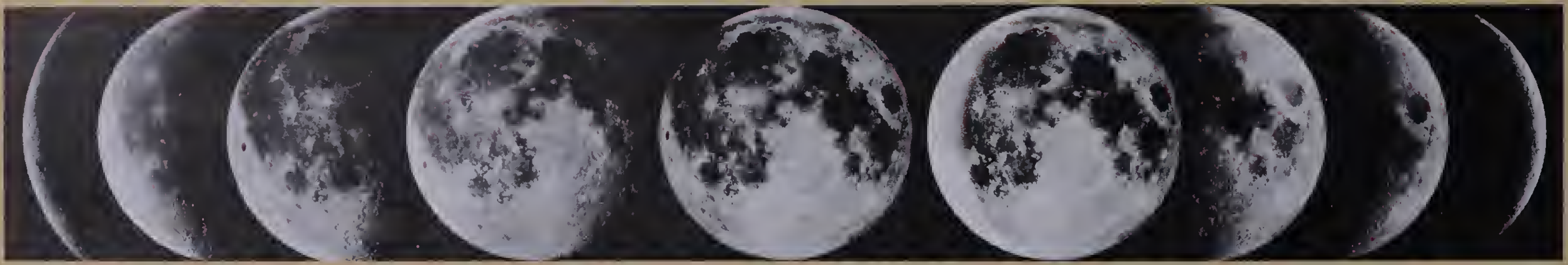
Can you do this and still keep the same side of the ball facing you? To check this, make a mark on the ball.

On the side facing the sun. Landings also are made on the side of the moon that is in sunlight. Then there is enough light to see by and to take pictures. Most often, the shaded side of the moon is too dark.

The moon gets direct sunlight on only one side—the side that faces the sun. But, most often, the side facing the sun is not the same as the side facing the earth. This is because the sun and earth usually have different positions in the sky, as seen from the moon.

And so, to have sunlight, landing places on the moon must be on the side facing the sun. At the same time, to have communication with the earth, they must be on the side facing the earth.





SOME THINGS TO OBSERVE

1. Where on the moon is there a place that faces the earth and the sun at the same time?

Stand outdoors in the sunlight. Hold up a ball at arm's length. Try to keep the shadows of your fingers and head from falling on the ball.

Now look at the part of the ball that is in direct sunlight. This is the area of the ball facing both you and the sun. Notice how the size and shape of this area changes when you move the ball.

Can you hold the ball so that all of its sunlit side faces you? Can you hold it so that all of its sunlit side is turned away from you? In what position must you hold the ball to be able to see half of its sunlit side? Only a little of it?

Now suppose the ball is the moon, and your head is the earth. Then in what area of the moon should landings be made? How does this area change as the moon circles the earth?

2. Watch for the moon in the sky. You often can see it in the daytime, as well as at night.

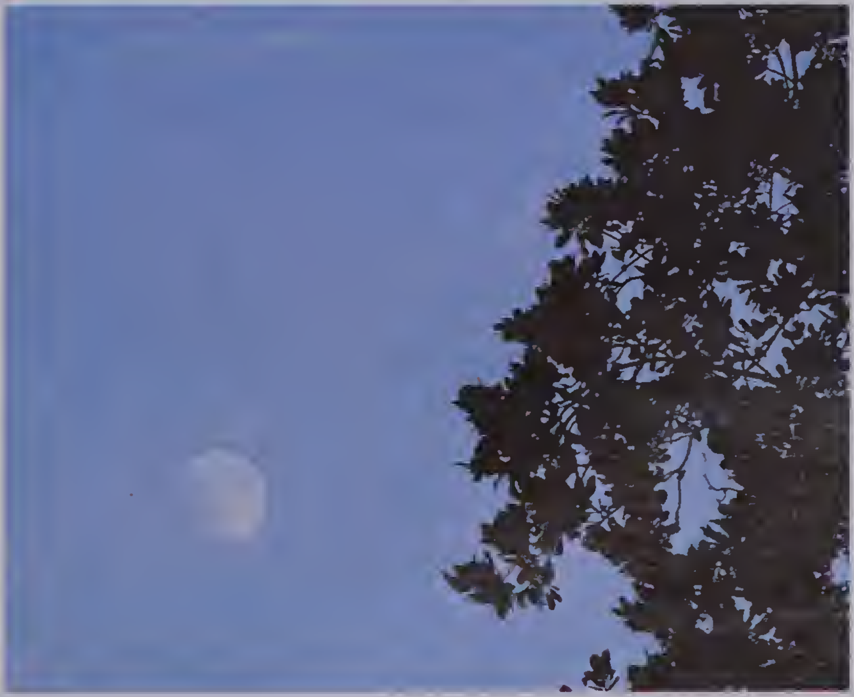
Which part of the moon is facing both the earth and the sun? Could a person in this area of the moon see the earth and the sun at the same time? If so, would they be in the same position in that person's sky?

Check the moon every day for a few days. Does the area that you see change? In what way?

Phases of the moon. When you hold up a ball in sunlight, one side is lighted by the sun. You may see all of this sunlit side, part of it, or none of it. It depends on where the ball is in relation to the sun and you.

The same is true of the moon. One side of the moon is lighted by the sun. But we see different amounts of this sunlit side at different times. It depends on where the moon is in relation to the sun and to us.

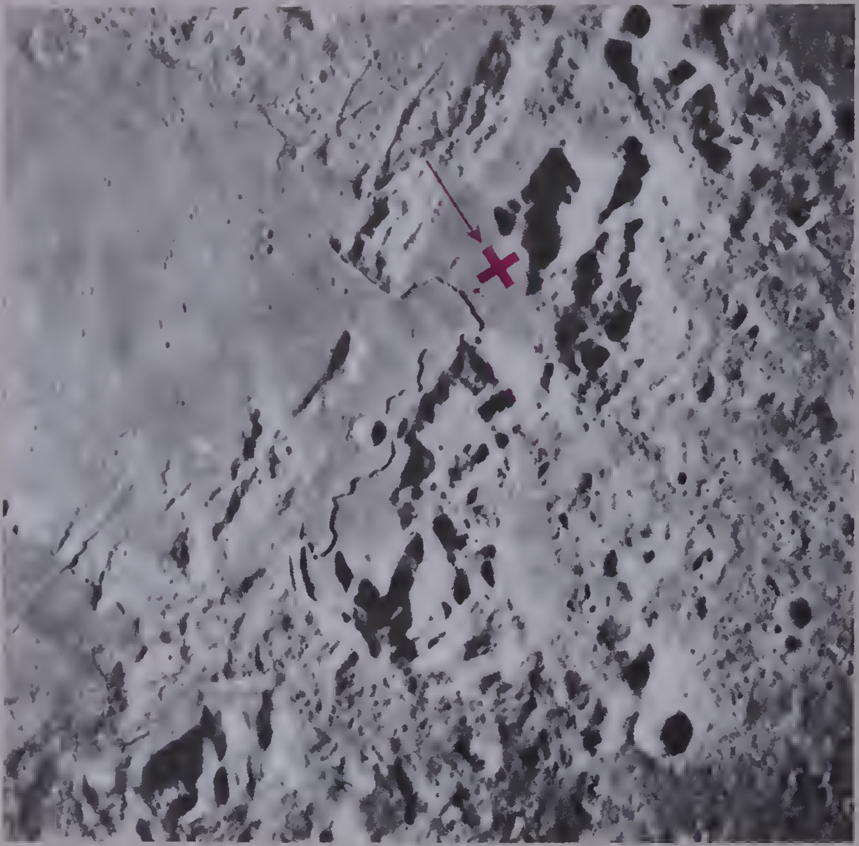
As you know, the moon revolves around the earth. Thus, its position keeps changing in relation to the sun. This causes a change in how much we are able to see of the moon's sunlit side. Because of this, the moon appears in different shapes, or *phases*. These phases change in a regular order.



A PROBLEM

Suppose a spacecraft blasts off when we see a half moon. It takes three days to reach the moon. It lands in the area that faces both the earth and the sun. By the time it lands, is this area smaller or larger than at the time of blast-off? Or does this depend on where the moon is in its orbit?

You can answer this with the help of a globe, a ball, and sunlight.



A photograph of the moon's surface, marked with a possible landing place.

At interesting places. Landings are made on fairly level and smooth places on the moon. They are near things that scientists want to observe and collect samples from.

With even a small telescope you can see that the moon has high and low places. It has rough areas on its surface, as well as smooth ones.

What the moon's surface is like can best be seen where sunlight strikes it at a slant. There the mountains and *craters* cast long shadows. On a half moon, where do you suppose the shadows of mountains and craters show up best? Why do you think so? Do they show up as well when the moon is full? You can find out by holding up a golf ball in sunlight!

Of course, telescopes make the moon appear bigger. With large telescopes we can get photographs of the moon's surface. But even the best pictures taken from the earth are not good enough for choosing landing places. They do not show enough detail.

Therefore, pictures have been taken from much closer to the moon. These pictures have been taken from *satellites* that travel around the moon. Pictures taken from satellites show small details. They even show craters and rocks that are only a few metres across!

From these pictures very good maps and models may be made of the moon's surface.

The astronauts who went to the moon opened up a whole new age of exploration. But little was discovered that was much different from what was expected.

Conditions on the moon. The astronauts found the force of gravity to be what had been expected. On the moon's surface, gravity is only about one-sixth as strong as it is on earth. So, the astronauts and their equipment weighed only about one-sixth as much as on the earth.

This made it easy for them to take giant steps. They could walk easily, and pick up many samples of moon rocks. When brought to the earth, these rocks became about six times heavier than they were on the moon!

Moon rocks

SOMETHING TO THINK ABOUT

A moon rock weighs about six times as much on the earth as it did on the moon. But what about its mass—the amount of matter in the rock?

Do you think that the mass of the rock is any different on the earth than it was on the moon? How could someone find out?

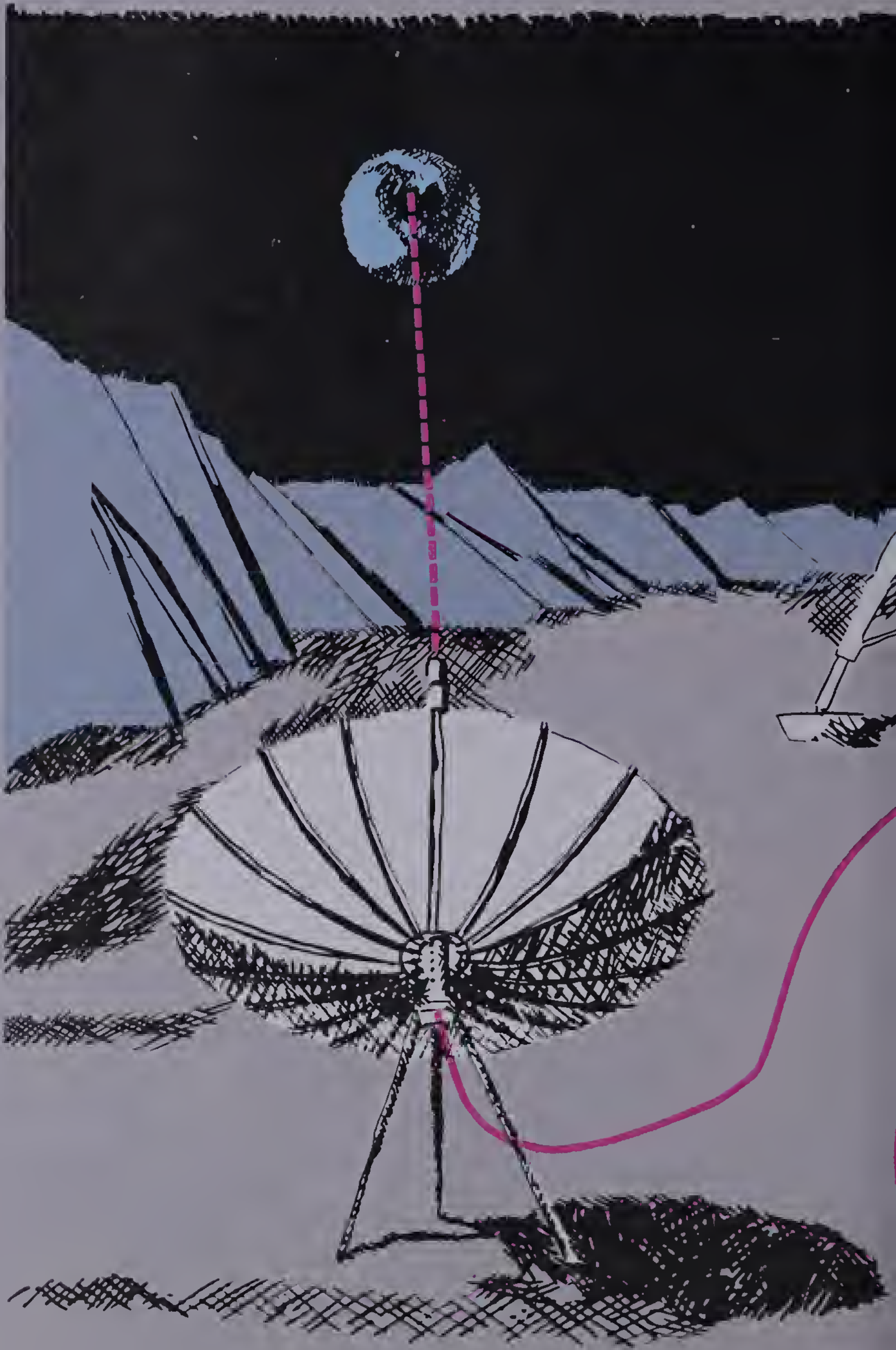
As expected, the astronauts found no air on the moon. Therefore, they had to wear airtight space suits, with oxygen inside. In this way they could get oxygen to breathe.

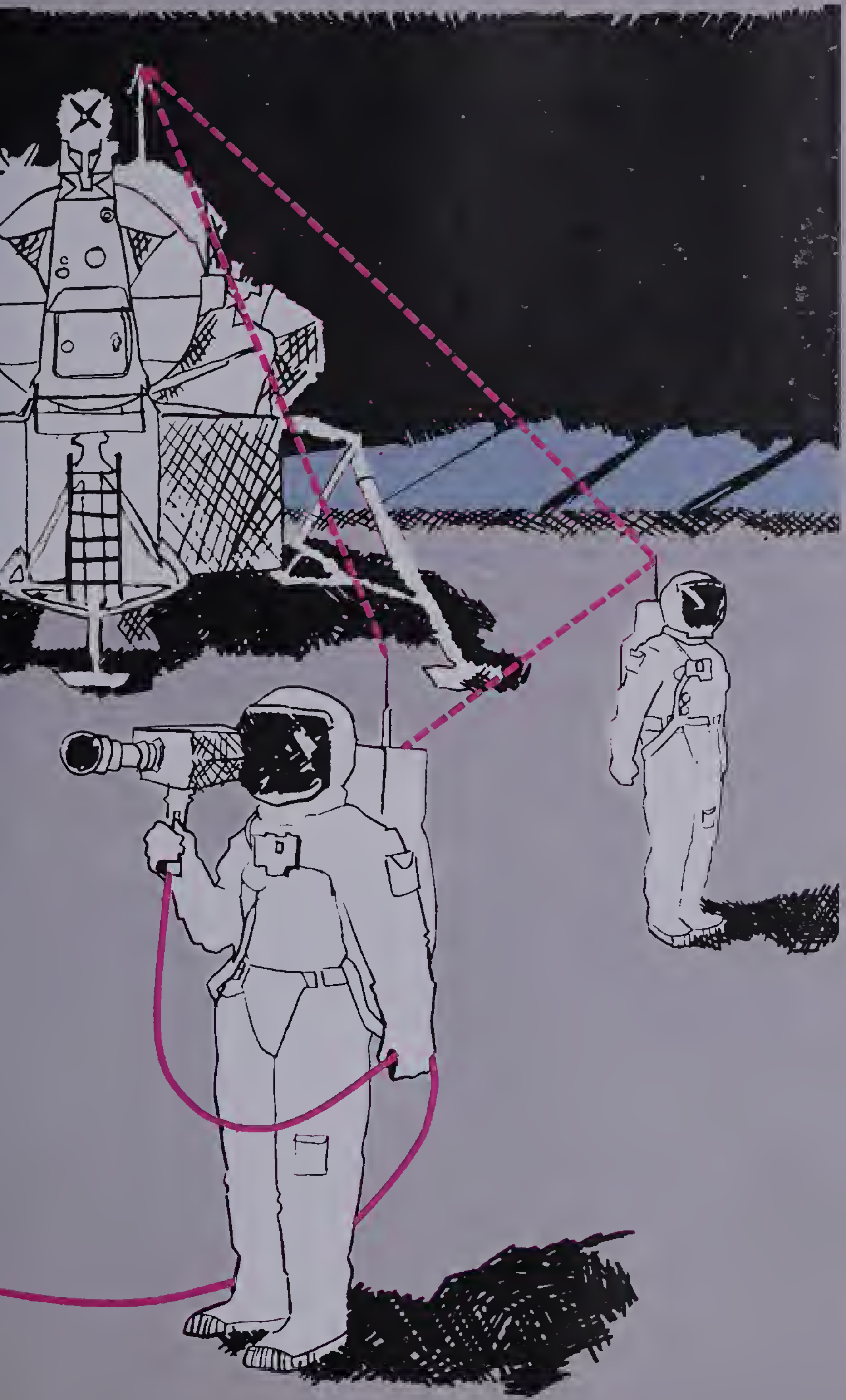
On the moon there is no air through which sound can travel. So the astronauts could not speak directly to each other. They had to use radio sets built into their space suits.

People on earth could hear the astronauts, too, but only by radio and television. Unlike sound, radio and television signals can travel through empty space. They go very fast—about 300 000 km per second. Even so, the signals take more than 1.25 seconds to get from the moon to the earth. Thus there was a slight delay each time an astronaut answered someone on the earth.

Light energy can travel through empty space, too. Therefore the astronauts could see clearly and take good pictures. They found the direct sunlight to be very bright. Of course, they did not look directly at the sun, because it would have harmed their eyes.

Shadows on the moon are very dark. This is because there is no air or haze to reflect sunlight into the shadows.



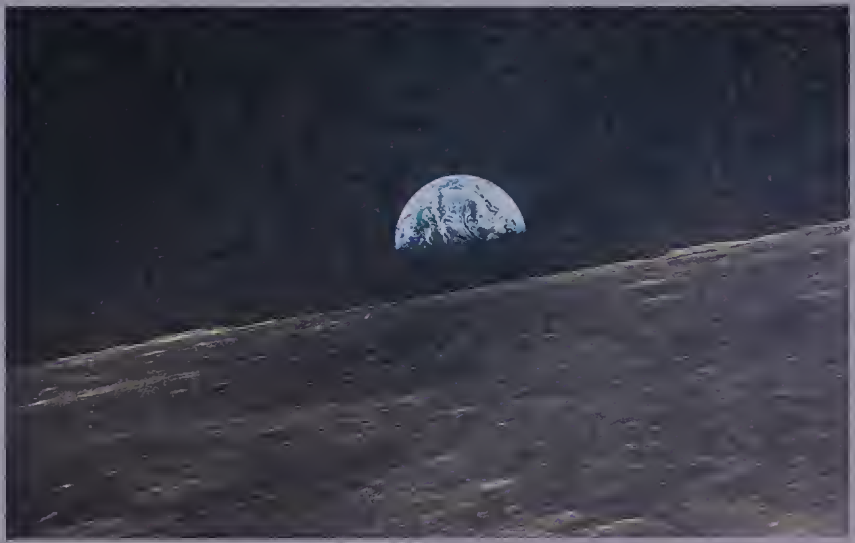


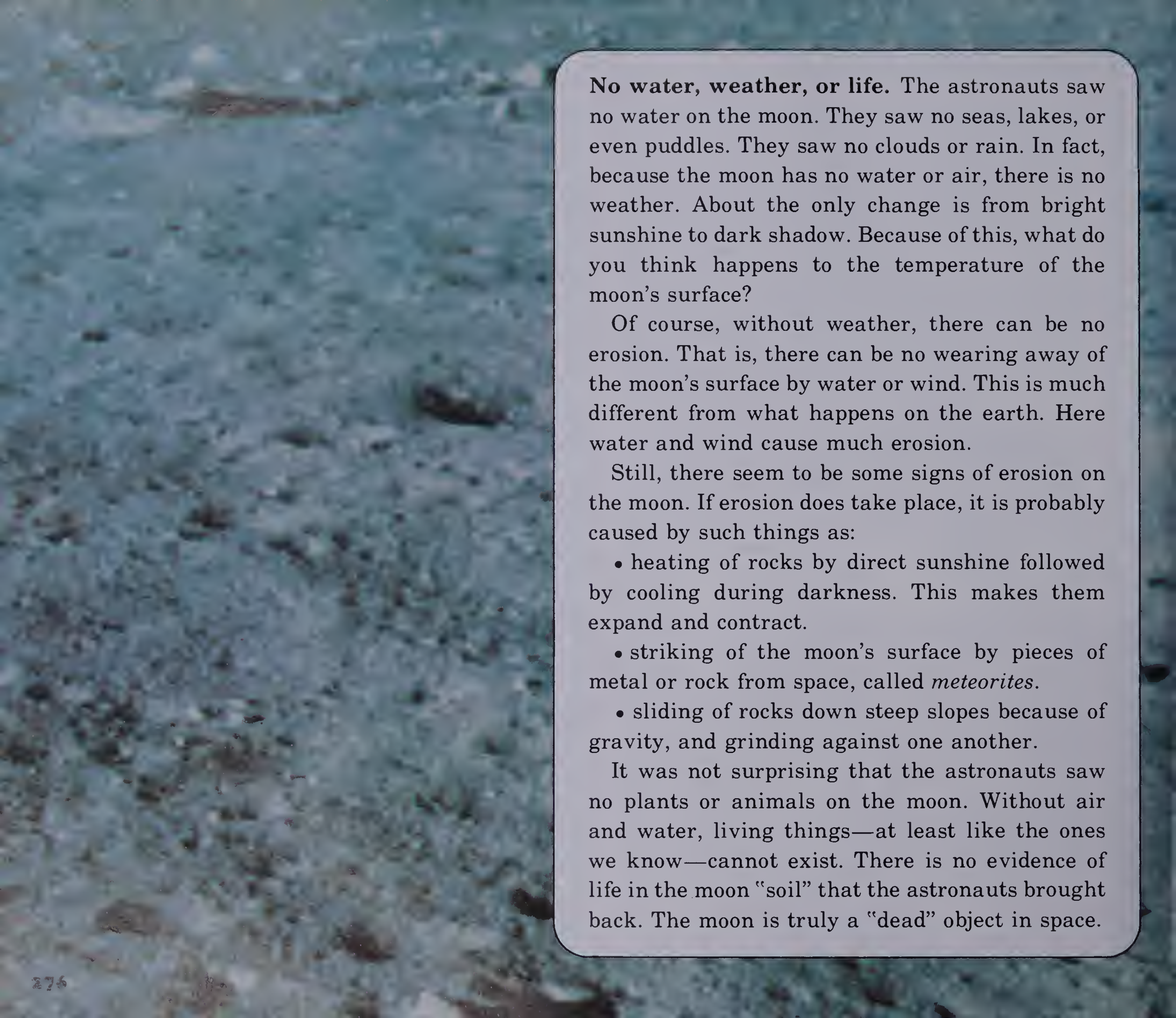
The moon's sky. Because there is no air around the moon, the sky appeared black to the astronauts—even though the sun was shining!

They also could see the earth shining in the sky, by reflected light. There is a great amount of water and air on the earth. So, it appeared bluish. The astronauts could make out oceans and continents, as well as large masses of clouds.

As seen from the moon, the earth appears to change its shape. It goes through phases like those we see of the moon, and for the same reason.

The earth is lighted by the sun on only one side. Astronauts on the moon can usually see only a part of this sunlit side. How much of it they see depends on the relative positions of the earth, sun, and moon. This changes as the moon revolves around the earth.





No water, weather, or life. The astronauts saw no water on the moon. They saw no seas, lakes, or even puddles. They saw no clouds or rain. In fact, because the moon has no water or air, there is no weather. About the only change is from bright sunshine to dark shadow. Because of this, what do you think happens to the temperature of the moon's surface?

Of course, without weather, there can be no erosion. That is, there can be no wearing away of the moon's surface by water or wind. This is much different from what happens on the earth. Here water and wind cause much erosion.

Still, there seem to be some signs of erosion on the moon. If erosion does take place, it is probably caused by such things as:

- heating of rocks by direct sunshine followed by cooling during darkness. This makes them expand and contract.
- striking of the moon's surface by pieces of metal or rock from space, called *meteorites*.
- sliding of rocks down steep slopes because of gravity, and grinding against one another.

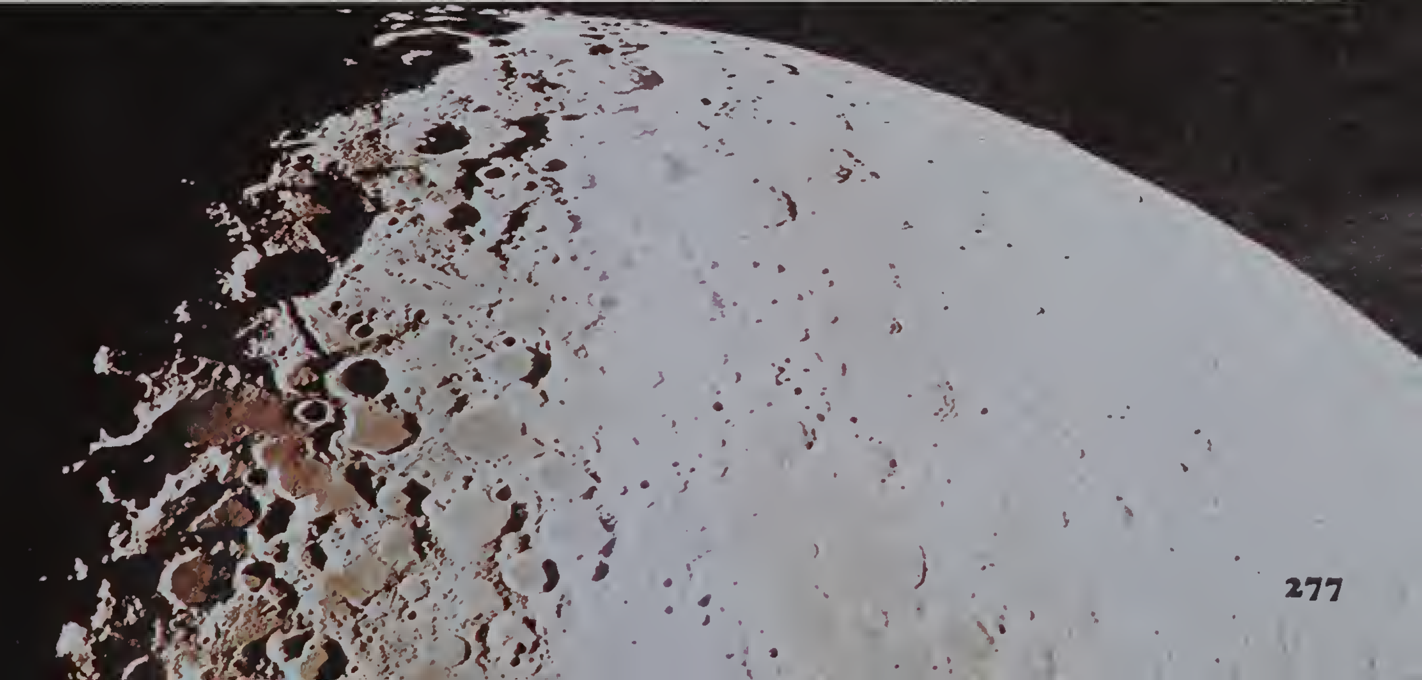
It was not surprising that the astronauts saw no plants or animals on the moon. Without air and water, living things—at least like the ones we know—cannot exist. There is no evidence of life in the moon "soil" that the astronauts brought back. The moon is truly a "dead" object in space.

New discoveries. Because of trips to the moon, people have discovered some things they did not know before. For example:

- There are very many craters on the moon's surface—even tiny ones.
- Some craters appear to have been formed by meteorites, and others by gas escaping from hot, liquid lava.
- Many of the rocks found are much like lava and ash from volcanoes on the earth.
- Some rocks found on the moon seem to be extremely old—more than four billion years!
- Just as the earth has *earthquakes* that cause the ground to shake, the moon has *moonquakes*.

Things still to be learned. There are still many things that we do not know about the moon. There is a great deal yet to be learned about it.

- We are not sure that the moon rocks brought back by the astronauts are a fair sample. The rocks came from only a few places. They may not be like those found everywhere on the moon. How do you think we could get a wider sample?
- We do not know what there is deep inside the moon. The astronauts could collect materials only from the surface and core samples from holes that they drilled.
- We have no evidence that anything is living on the moon. But is it possible that living things did exist on the moon at one time? If so, how might we find out about them?
- We are not sure whether volcanic activity is still going on in some places on the moon. It may even be that water is being given off as a gas from hot lava below the surface. How could we find out about volcanic activity on the moon?



Ideas for REVIEW

- The distance to the moon can be figured by timing how long it takes a radio signal to get to the moon and return to earth.
- The distance to the moon can be figured by astronomers thousands of kilometres apart. They take pictures of the moon and stars near it. Then they look at the position of the moon in relation to the stars in each picture.

- It is about 375 000 km to the moon, as far as 9.5 trips around the earth.
- To send an object to the moon, there must be a very great push. This is because the earth pulls on an object with a force called gravity.
- The earth rotates from west to east. This happens once every day.
- The moon revolves around the earth from west to east, once in about a month.
- The moon's position in the sky keeps changing. This is because the earth rotates and the moon revolves around the earth.
- The same side of the moon always faces the earth.
- Because the moon revolves around the earth, its position keeps changing in relation to the sun. Therefore, we see different amounts of the moon's sunlit side.
- On the moon's surface, the force of gravity is about one-sixth as strong as it is on earth.
- The moon has no atmosphere.
- There is no evidence of water, weather, or life on the moon.

TEST Your Understanding

A. Use the words from the following list to make each sentence correct. Each word is used only once. Write your answers on a piece of paper. *Do not write in this book.*

oxygen
revolves
straight
gravity
sun
rocks
earth
atmosphere
phases
rotates
movements

1. The earth's _____ becomes thinner with height.

2. Today, only rocket engines can give a spacecraft a great enough push to overcome the earth's _____ .

3. The sun, moon, and stars seem to move across the sky because the earth _____ .

4. The moon moves, or _____ , around the earth.

5. To send a spacecraft to the moon, people have to take into account the _____ of both the earth and the moon.

6. Radio and television signals travel through space only in _____ lines.

7. The moon appears in different shapes, or _____ .

8. Landing places on the moon are chosen because they face both the _____ and the _____ .

9. Astronauts have _____ in their space suits because there is no air on the moon.

10. Some _____ found on the moon are billions of years old.

B. On your paper, write one or two sentences for each of the following.

11. Explain how pushes are important in sending a spacecraft to the moon.

12. Tell where an astronaut would have to stand on the moon to see the earth and sun at the same time.

13. Making use of what you know about the moon, tell why the moon has no living things—at least like the ones we know.

14. People still have questions about the moon. Choose one or two things that people still do not know about the moon. Suggest ways in which people might find out what they want to know.

C. On your paper, draw a picture of the earth and the moon. Use arrows to show their motions.

PROBLEMS

1. Some of these photographs were taken on the moon. The others were taken on the earth. Which were taken on the moon? Which were taken on the earth? How can you tell?

What important differences can you discover between the moon and earth photographs? What conditions on the moon and earth do you think caused these differences?

2. On a trip to the moon, astronauts must take along everything they need. What do they need?

Imagine that your whole class is to stay in your classroom for a week. No one will be able to enter the room or leave. All windows and doors will be locked and sealed airtight.

What would you take into the room before it is sealed? Think of all the things you would need.

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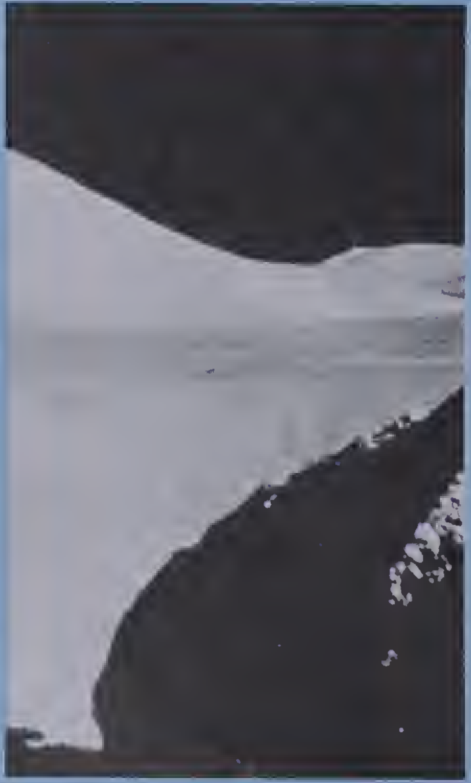
b



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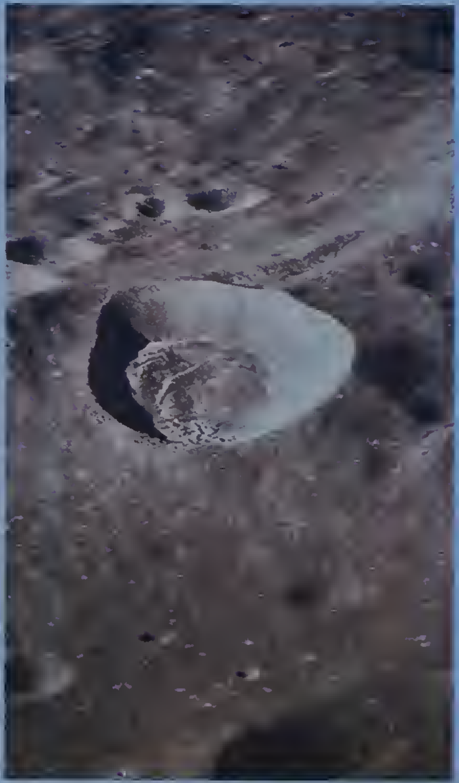

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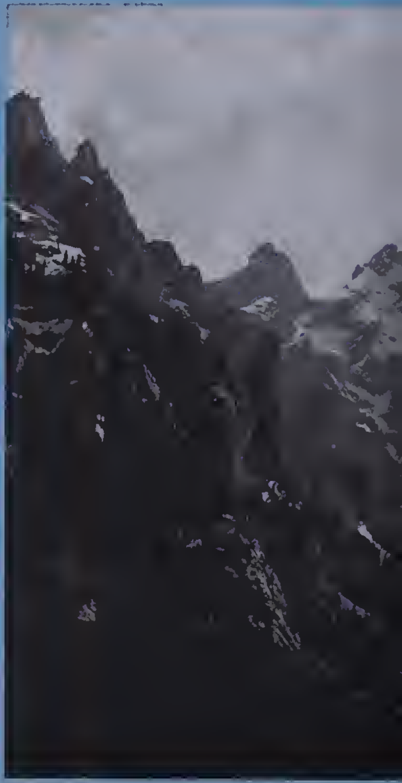

List them by groups. Then add your list to a list that the whole class puts together.

What things do you think are the most important? What are some that are less necessary? Are there any that you are not sure about or cannot agree on?

Don't forget, there also must be ways of getting rid of waste materials!

FIND OUT on Your Own

1. Keep a record of phases of the moon. Find out how many days pass from new moon to new moon. Record how many days the moon is in the quarter phase, in the half-moon phase, and so on.

2. Find out about a lunar eclipse. Find out how it is different from a solar eclipse. Then draw pictures to show what happens during each kind of eclipse.

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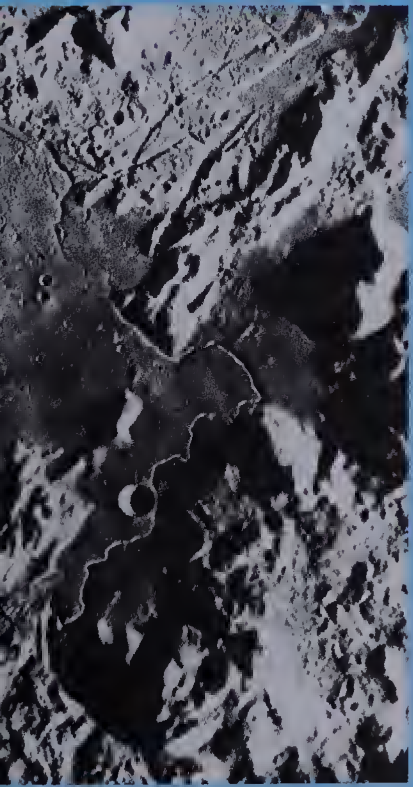

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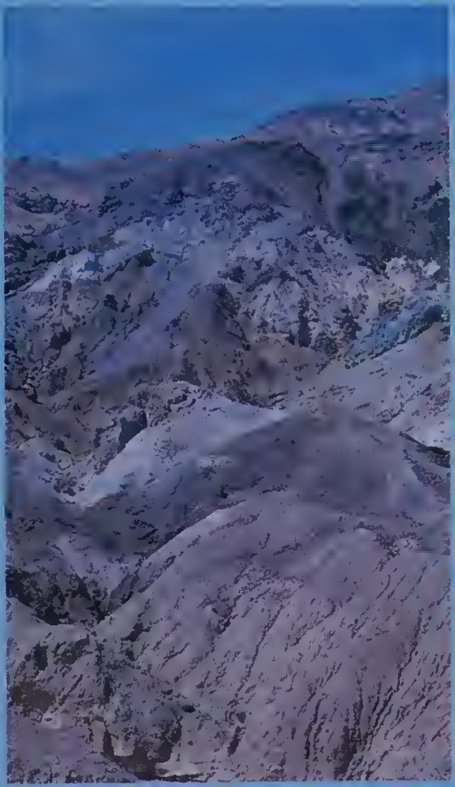

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10 Interdependence of Living Things

Are all organisms *interdependent*? Do they depend on other organisms for many of the things they need? Are they interdependent with the same kind of organisms? With different kinds of organisms?

What two kinds of living things do you see in the picture? Each depends on the other for something. The men get honey from the bees. What do these bees get from the men?

Bees also depend on each other. They work together to build the hive, make food, and raise new bees. How are the men in the picture dependent on other people?

One Living Thing Depends on Another

LESSON 1

Cows depend upon grass. It is their source of food.

People depend upon cows for some of their food. Some cows produce milk, a source of butter and cheese. Other cows are a source of beef and leather. But if there were no grass, there would be no cows. So people depend, in a way, upon grass.

Suppose a farmer did not take care of a pasture. Then weeds and bushes might replace the grass. Cows probably would not eat these plants. They prefer grass. When a pasture is cared for, it produces plenty of food for cows. In that way, it produces plenty of food for us. So grass depends in part upon people.

Cows depend upon grass. Grass depends upon people. People depend upon cows. People, cows, and grass are interdependent.

Interdependence may be simple. If two living things depend mostly upon each other, then interdependence is simple. A *lichen* is an example of this. Lichens grow mostly on soil, big rocks, and tree trunks. Lichens are shown above.

A lichen is not one plant. It is a kind of partnership between two plants, an *alga* and a *fungus*. An alga is a food-making plant. A fungus is not. So, it depends upon the alga for food. The alga depends upon the fungus for protection and for moisture. This partnership lets lichens grow where neither an alga nor a fungus could grow alone.

Usually interdependence is complex. Interdependence in a lichen is simple. Other living things are not a part of it. But with most living things, interdependence is complex.

For example, cows eat grass, but they cannot digest the grass by themselves. They need the help of certain one-celled living things called *bacteria*. These bacteria live in cows' digestive systems. They break down the chemicals in grass. In return, they have a warm, safe place to live inside the cows. Chewed grass is their food. The interdependence of cows and grass is not simple. It is complex!

SOMETHING TO DO

In the fall, after songbirds have raised their young, collect an empty nest. Then spread paper on the floor. Carefully take the nest apart. Try not to lose anything that might be in the nest.

Put all materials of each kind in separate piles. Make a list of these. How many different kinds of materials were used in the nest? How many kinds of living things produced these materials? What evidence is there that the nest was used by animals other than birds?

What happens to one affects another. It may seem what happens to one kind of organism does not affect others in the same environment. But often something happens to show that these organisms really are interdependent.

For years, a certain marsh was famous because many ducks nested there. Snapping turtles and skunks lived there, too. At one time, when the price of skins was high, many skunks were trapped. Soon, there were few skunks left. But there were few ducklings, too. People got worried.

Then they found that skunks dig up and eat the eggs of snapping turtles. Snapping turtles feed upon fish and other animals. They also eat ducklings. Without skunks to eat turtle eggs, the number of turtles increased. The turtles, in turn, ate a lot of ducklings.

Then, trapping of skunks was stopped. After a while there were few turtles. But there were many more ducklings. Was interdependence more important here than people first thought?

What did you eat for breakfast today? From what kinds of living things did your food come? In a big breakfast, as shown above, the orange juice came from a green plant. The milk came from a cow. The eggs came from a chicken. The bacon came from a pig. The bread came from wheat.

Every food in this breakfast was part of a living thing. Now it is food for another living thing! Maybe for you!

Do most living things become food for others? How about the organisms in a vacant lot, a woods, a pond, the sea?

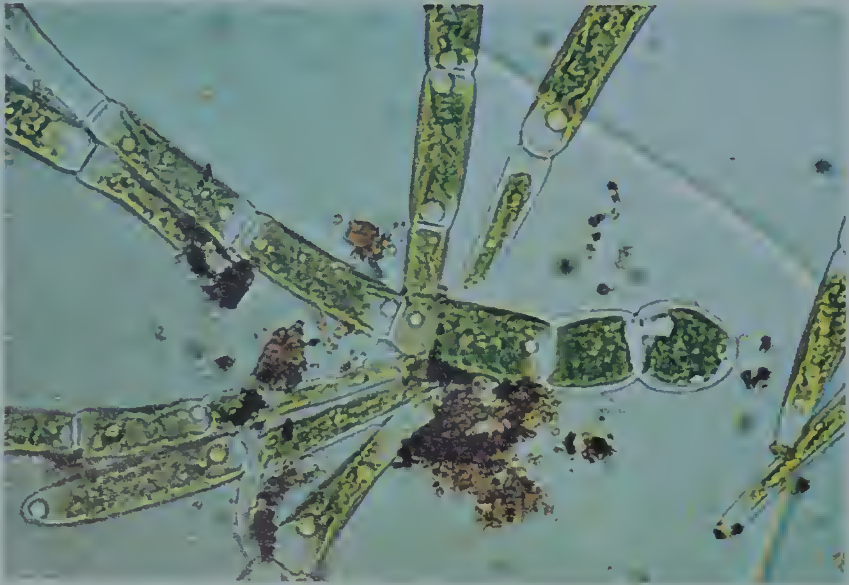
SOMETHING TO TRY

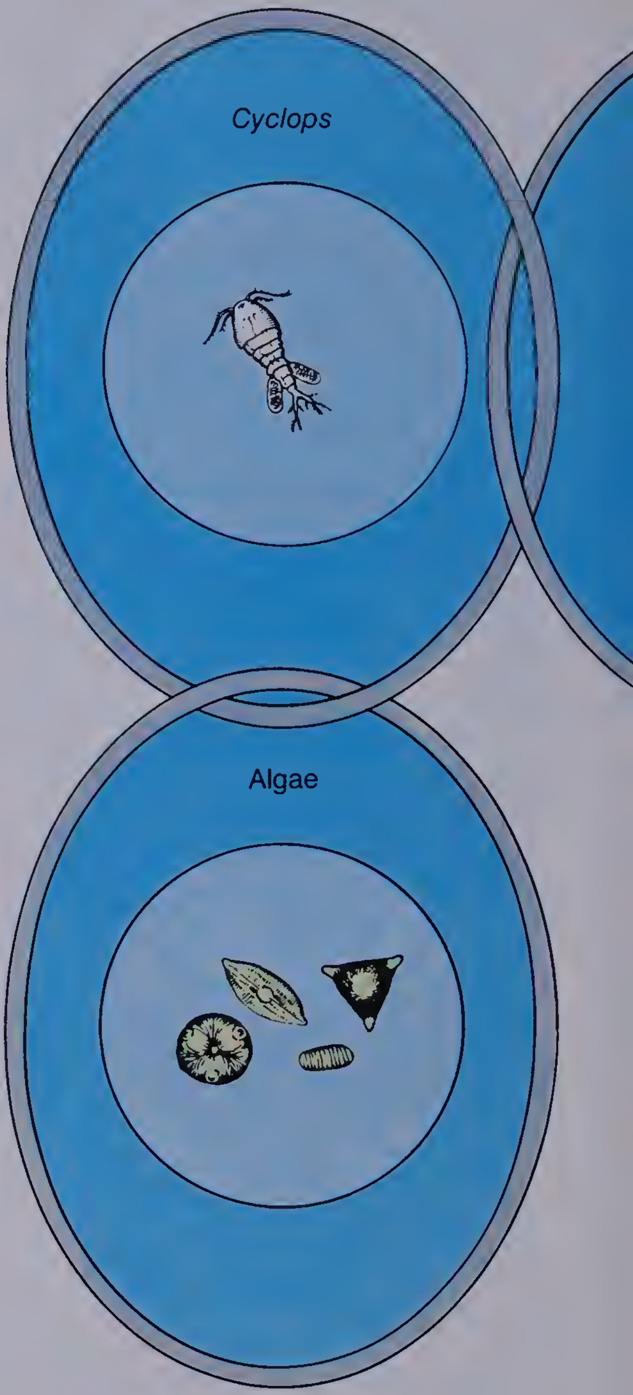
Get a sample of water from a pond, ditch, or aquarium. Be sure that it has a greenish color or has some green stuff in it. Put a drop of water containing green stuff on a microscope slide. Cover it with a cover glass. Then, look at it under a microscope.

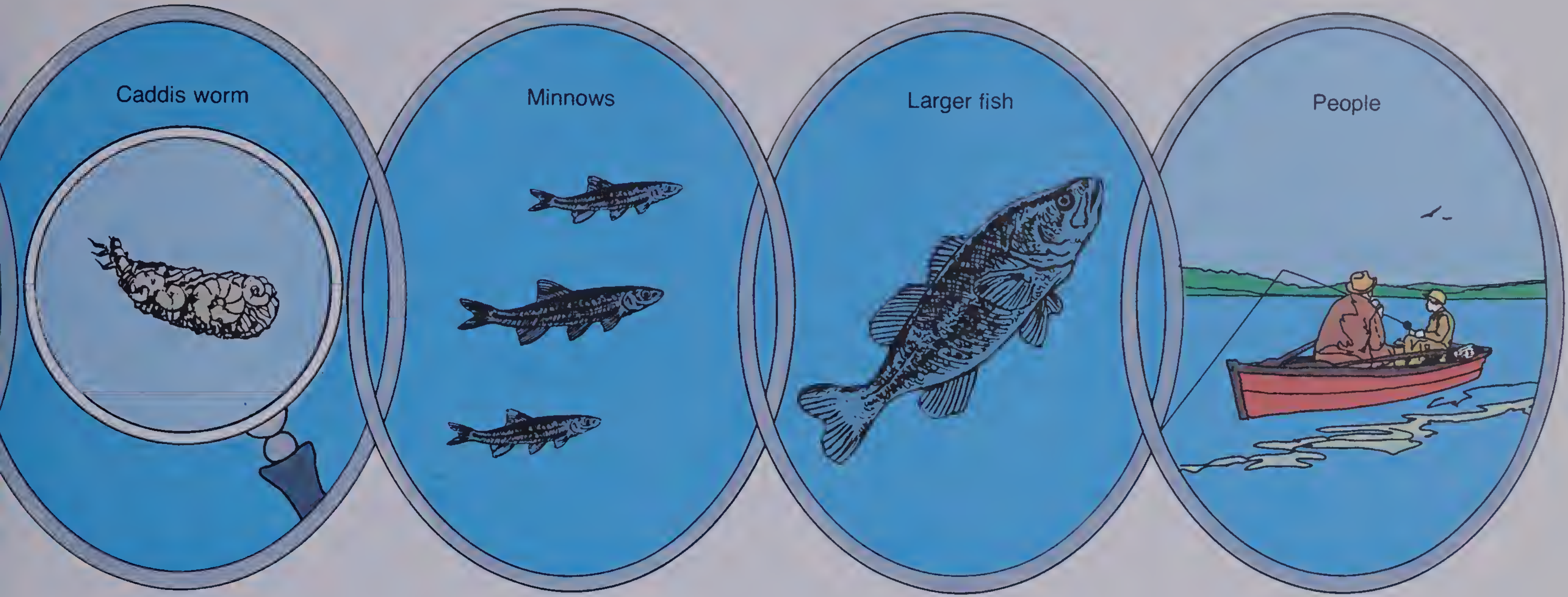
What do the green bits look like? Do any appear to be in strings or chains? In clusters? In single bits? Do any seem to move?

These green bits are probably algae. Algae are plants that do not have roots, stems, or leaves. Algae is the plural word for alga. Most kinds do not move by themselves. They just float around in water. Sometimes they become attached to stones and other surfaces.

Algae are used as food by small animals just as grass is used as food by cows. Bits of algae may be so small that you cannot see animals eat them.







Pathway to dinner—a food chain. Suppose that in a pond some algae are eaten by a tiny animal such as *Cyclops*. *Cyclops* is smaller than a pinhead and nearly white. It is a common fresh-water animal.

Cyclops, in turn, is eaten by many other kinds of animals. One such animal is an insect larva called a caddis worm. Caddis worms build snug cases out of bits of material from the pond bottom.

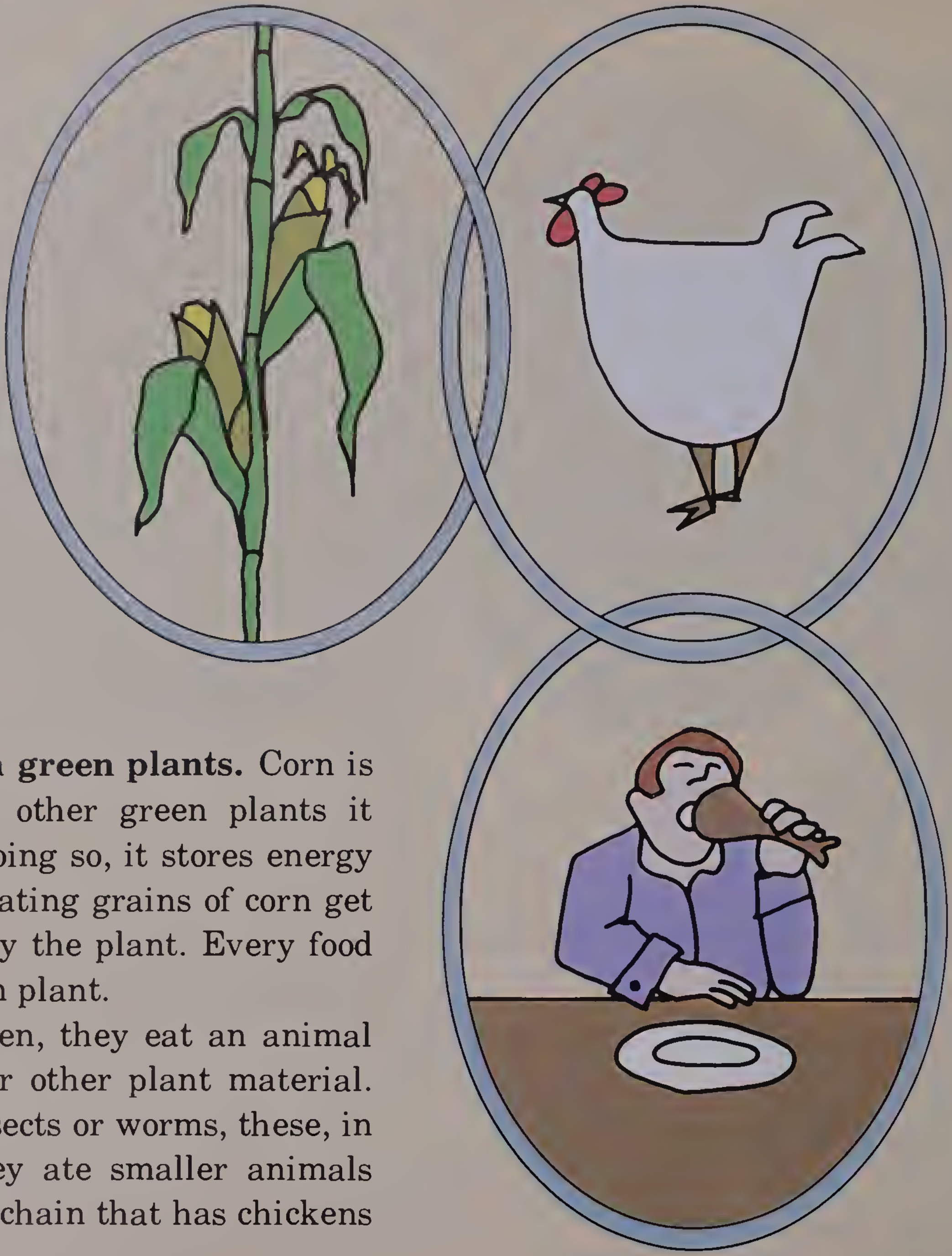
Caddis worms, in turn, often become food for certain small fish or minnows. Minnows eat many kinds of living things. Caddis worms are only one of their foods.

Some minnows become food for still larger fish. These large fish often become food for people.

Cyclops feeds on algae. Caddis worms feed on *Cyclops*. Minnows feed on caddis worms. Large fish feed on minnows. We sometimes feed on large fish. Food and feeder, each in turn, make up a *food chain.*

This food chain begins with algae. They are the first *link* in the food chain. Each of the other organisms is another link.

Each link in a food chain is important. When one kind of animal is killed off, the organisms that depend upon it may suffer or die.



Food chains begin with green plants. Corn is a green plant. Like all other green plants it makes its own food. In doing so, it stores energy from sunlight. Animals eating grains of corn get energy that was stored by the plant. Every food chain begins with a green plant.

When people eat chicken, they eat an animal that, in turn, ate corn or other plant material. Even if a chicken eats insects or worms, these, in turn, ate plants. Or, they ate smaller animals that ate plants. Any food chain that has chickens begins with green plants.

Producers and consumers. Because green plants produce their own food, they are called *producers*. Grass is a producer. Corn is a producer. So are oak trees, ferns, and algae. What is the largest producer near your school? What is the smallest? The most numerous?

Some organisms do not make food. Instead they use, or *consume,* food stored in another organism. They are *consumers*. A chicken is a consumer. It consumes what a producer, such as corn, makes.

You are a consumer. Sometimes you consume a producer directly, as when you eat lettuce, potatoes, or rice. But often you consume a producer indirectly. Have you ever eaten a consumer that ate a consumer that ate a producer?

SOMETHING TO DO

Diagram some food chains.

First, write the names of five animals across the top of a sheet of paper. Under each, write the name of an important food for that animal. If that food, in turn, is an animal, write one of its main foods below it. Keep doing this until you have the name of the organism with which that food chain began. If that name is a green plant, or part of a green plant, circle it in green. This is a producer.

Can you find any animal whose food chain does not begin with a producer? What is the longest food chain you can show? The shortest?

Lion	Fly	Starling	Snake	Shark
zebra				
grass				

Cockroach

Seagull

Vulture

Crow

Fly

Scavengers. In time, nearly all organisms die. Even when they do, they become food for other organisms. So the food chain keeps going.

Suppose that a fish dies and is washed up on shore. Some kinds of birds may feed on it. Flies visit it and lay eggs. Fly larvae soon feed on the fish. Before long, it begins to smell. Birds, insects, and the other organisms that feed on the dead fish are *scavengers*. They are as much a part of the food chain as the fish itself. Some scavengers are shown above.

Decaying fish

The last link. Dead organisms are also food for bacteria and fungi. Fungi is the plural word for fungus. You need a microscope to see bacteria.

Some bacteria cause disease. But mostly, bacteria help *decompose* dead organisms. They break down chemicals. When these chemicals return to soil, water, and air, they can be *recycled,* or used again, by living things. Green plants can use them when making new food.

Fungi, like bacteria, help to decompose stuff that once was living. *Decomposers* are the last link in nearly all food chains.

Bacteria

Fungus

Fungi

Decaying tree stump

The chemical cycle. Even though foods are destroyed, many of the chemicals in them get recycled. New producers use these chemicals again and again. So simple food chemicals really go in a *cycle*. They go from producers to consumers, and back to producers.

SOMETHING TO TRY

Examine and keep a record of what happens to a dead animal. Look for a small animal that has just died. When you find one, cover it with a piece of screen. Fasten this down tightly so that dogs and other scavengers will not drag the *carcass* away.

Visit the carcass each day for a week, and then each week for a month. Keep a record of any animal visitors that you see and any changes in the carcass.

What are some early visitors? How do you think they found the carcass? What other kinds of scavengers can you see? What does the carcass look like after a month?

Safety Note: *Be sure to wash your hands if you touched the carcass.*

PROBLEMS

1. How could fungi be a link in a food chain without being the last link?
2. What do you think it would be like on the earth if there were no bacteria or fungi?

Not All Food Becomes Part of Your Body

LESSON 3

Suppose that you could put into one place all the food that you eat in a year. How big a room do you think it would take? Would the food have a much greater mass than you do?

Suppose you eat an average amount of food. The total for one year might be as much as 500 kg. Yet, how many kilograms would you have gained? 3 kg? 5 kg? Certainly not 500 kg!

Little of what you eat becomes part of you. Most of it is water anyway. Much is lost as urine, perspiration, solid waste, and energy. Only a tiny bit becomes part of your body.

SOMETHING TO TRY

Find out how much of a potato may be wasted even before it is cooked. First, find the mass of a whole raw potato. Record it.

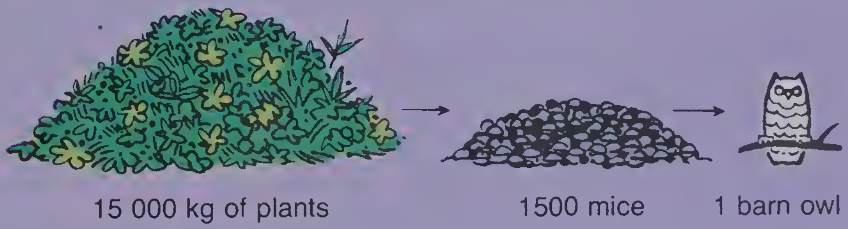
Next, peel the potato. Then find the mass of the peels. How does their mass compare with that of the unpeeled potato?

Figure out the number of times a year that you eat peeled potatoes. Then figure how much might be wasted in uneaten peels in one year. Much of the food value of a potato is in its peels.

Missing mass. Only a tiny bit of what any consumer eats becomes part of its body. It takes about 10 kg of hay to produce a kilogram of live beef. Or, it takes about two truck loads of hay to produce one beef cow. When a beef cow is killed, half of it cannot be used for meat. What is left for eating is only about half the original animal.

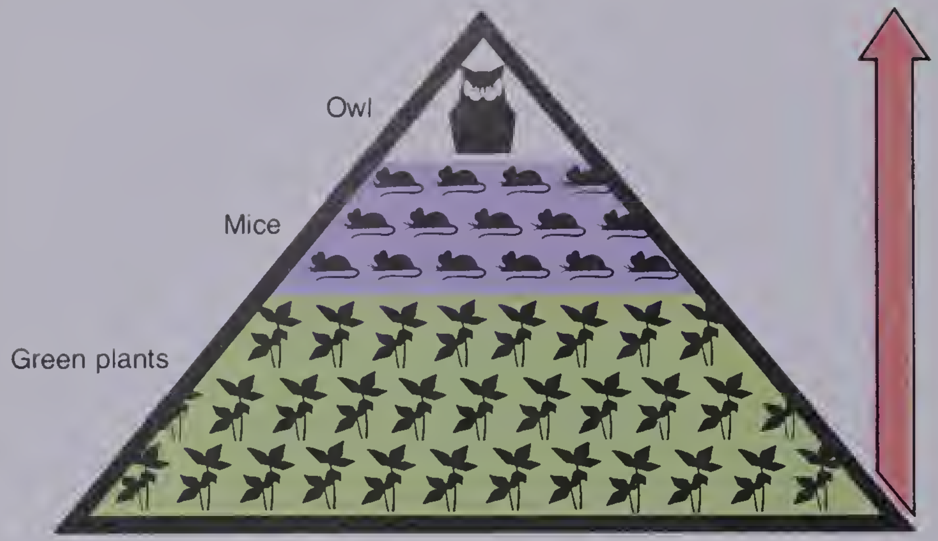
A pyramid of numbers. One barn owl, in a single year, may eat about 1500 mice. Each mouse, in turn, may eat more than 10 kg of green plants.

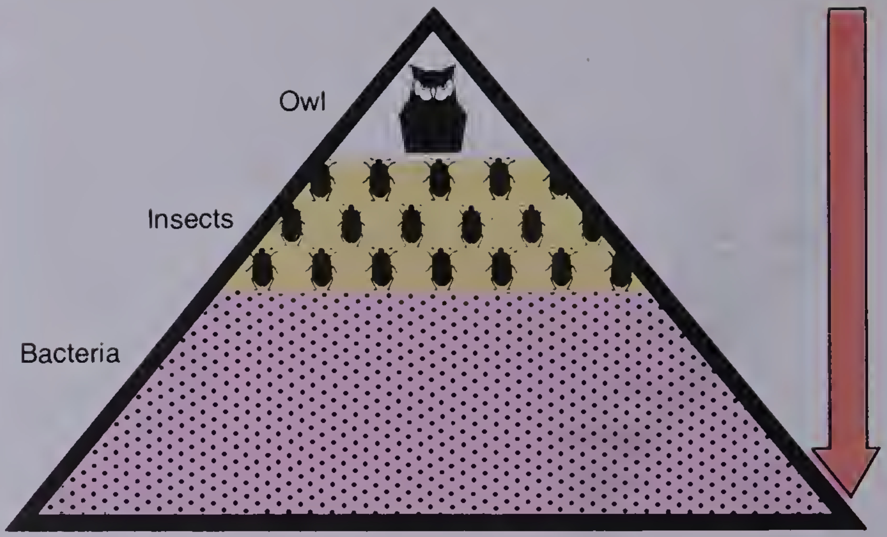
The food chain from green plants to barn owl is something like this.



Animals that catch and eat other animals are called *predators*. Owls are predators. Are people?

Suppose that the owl were food for another predator. Then it would take even more green plants to support the predator. Can you explain why this is true?





The number of living things in each link of a food chain can be shown as a *pyramid.* It is called a pyramid of numbers.

In this pyramid, green plants are the base. This means that all animals in the links above the base depend on green plants. Often, there are fewer living things in the link next to green plants, than there are green plants. Why do you think this is so?

With each higher link in this pyramid, the number of living things tends to get smaller. Would the total mass of living things at each higher link get smaller? Why do you think so?

The animal at the top. When the animal at the top of the pyramid dies, what happens to it? It may become food for small scavengers, such as insects. Or, it may become food for millions of bacteria. How might you show this?

It could be a pyramid of numbers, as before. But this time the direction is from top to bottom. There are more insects than owls, and there are many more bacteria than insects.

Look out your window. You probably can see many green plants, but few animals. Even in the sea, there are huge numbers of tiny green organisms. These are producers too small to see. But they are the food for tiny animals. And these are food for larger and larger animals, but smaller and smaller numbers of them.

It may take thousands of producers to make a predator. But after death, it may take thousands of scavengers and millions of bacteria to decompose the predator completely.

Organisms in Different Habitats LESSON 4

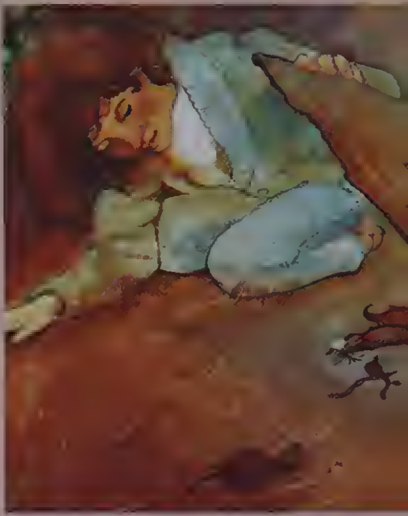
An organism's *habitat* is the place where it lives. This may be a pond, a woods, or under a log.

Not all organisms can live in the same kind of habitat. Different organisms need different conditions in order to live, as shown below.

A tadpole needs a lot of water. A lizard needs only a little. Tadpoles would die on land. On the other hand, lizards would die in a tadpole's habitat. One cannot live in the other's habitat.

The habitat of dandelions is open and sunny. The habitat for water moss is shady and wet. Water moss could not live where dandelions do.

Each kind of organism has certain needs. It gets the things it needs in a certain habitat.



SOMETHING TO TRY

Visit a habitat such as

- the top of a tree stump
- under flat stones on a hillside
- along the edge of a stream
- around weeds and other things in a vacant lot

Look at the organisms that live there. Try to decide what makes them well suited to that habitat.

What changes in the habitat might keep them from living there?

AN EXPERIMENT

Can you find some *isopods,* often called sow bugs? They are harmless scavengers.

Find out what kind of habitat isopods would select if they had a choice.

Collect 15 or 20 of them in a small jar. Then make a test box for them as follows.

Remove the lid from a large cardboard clothing box. Label one end "D" for dry, and the other end "W" for wet.

Next wet a paper towel. Fold it and place it at the end of the box labeled "W." Fold a dry towel the same way and place it at "D." Then put the lid on the box. Cut a hole the size of a five-cent piece in the center of the lid.

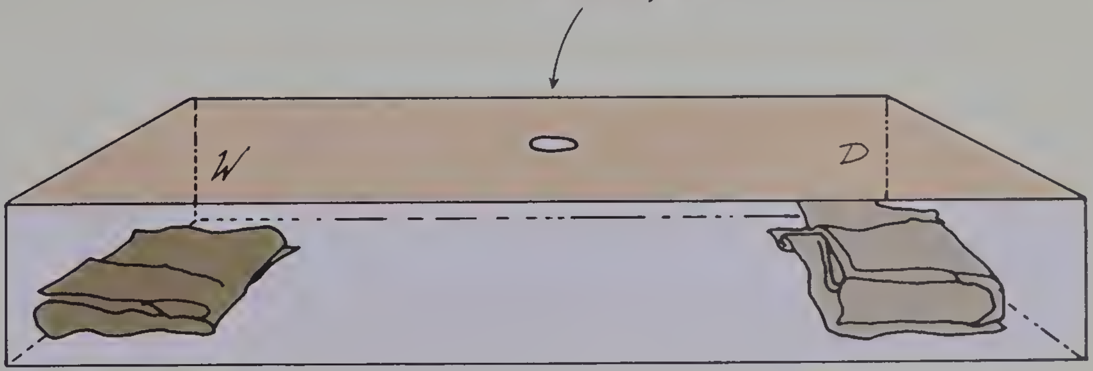
One by one, drop your isopods through the hole in the box. Wait 10 minutes. Then open the box and see where the isopods are.

Record what you saw on a chart. How does the number found at "W" compare with the number found at "D" or wandering?

How could you find out whether isopods prefer darkness or light? How would you change the box to do this? Try it. Then make a chart that shows whether these animals prefer a light or dark habitat.

From what you saw, what can you infer about the habitat isopods like best?

	Number found
at D	
at W	
Wandering	



SOMETHING FOR A GROUP TO TRY

With your friends, clear a patch of land about 2m on a side.

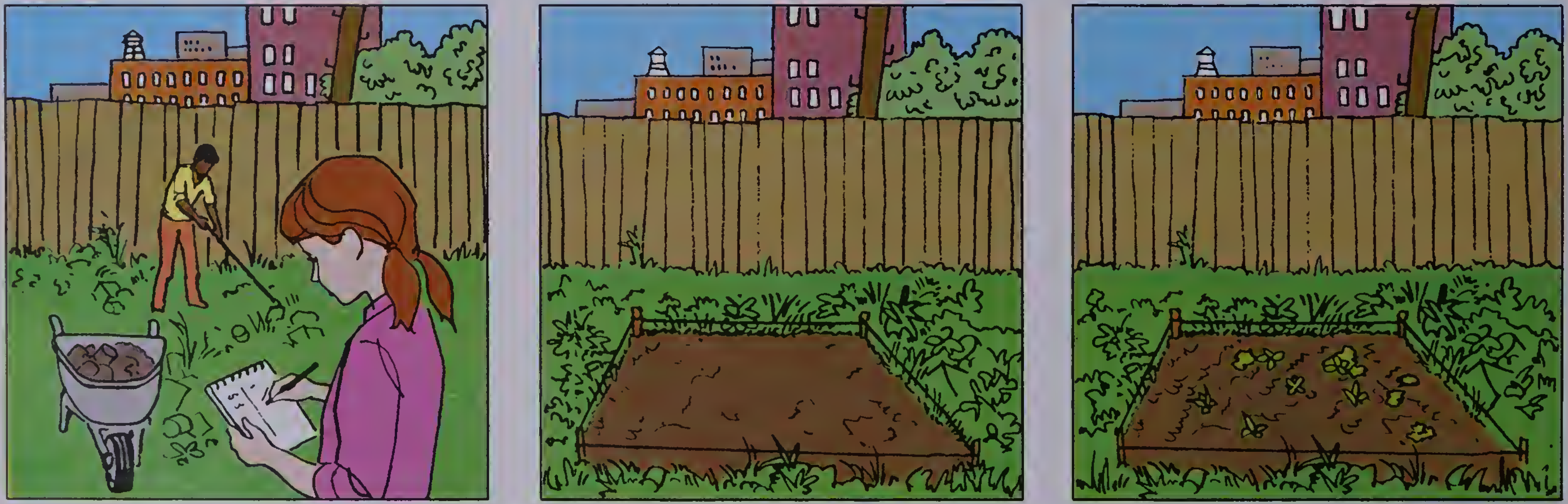
Before you start, make sure you have permission. Move all the animals to another area.

Keep a record of every kind of plant and animal you remove. If you do not know the names of certain species, draw them.

Then, once a week, return to the area and look at what is happening. When do you first see signs that life is returning? Which plants start to grow first? Is there any evidence of how they got there?

What kinds of animals return first?

How long does it take until the area looks the way it did before you cleared it?



The best suited return. Sometimes the plants and animals of an area are destroyed or removed. This could happen because of a forest fire. If the climate and soil are unchanged, the species that are best suited to the habitat will often return.

What animals might return first? Could owls return before mice? Caterpillars before green plants? Bark beetles before trees? Woodpeckers before beetles? Would spiders be more likely to return before raccoons? Why do you think so?

Changes in habitat. Some changes in a habitat are temporary. The habitat can be changed back to what it was. For example, a pasture that is plowed can become a pasture again. It just takes time. A forest can be destroyed by fire. Yet in time the land may become a forest again.

Some changes in a habitat cannot be reversed. They are permanent. People often cause permanent changes—sometimes without knowing it.

A clean, beautiful river such as the one in the picture can supply power for industry. A city often develops where such a river meets a lake or the sea. In time, pollution from factories and sewage can change the river. Most living things can no longer live there. Then the river becomes "dead." It may never recover!

Our Interdependence with Other Organisms LESSON 5

All of the living things in an area make up a *community*. The area in which you live is a community. And you are a member of that community. So are all other organisms in the area.

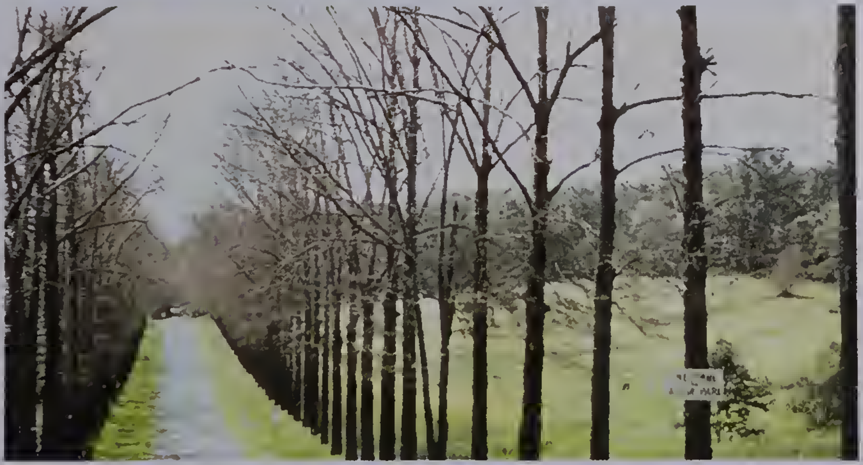
Members of a community are interdependent. People are interdependent with other organisms. People can cause great changes in a community. Sometimes these changes are harmful to many other members of that community.

Removing a member. Sometimes people remove one kind of organism from a community without first studying what might happen. It could be a serious mistake.

About 70 years ago, 4000 deer lived on the Kaibab Plateau near the Grand Canyon. People who wanted more deer thought it would help if they killed off the deer's predators. So they trapped and killed wolves and mountain lions.

The number of deer began to increase. In fact, the deer increased so rapidly that in 20 years there were 100 000! But there were not enough green plants to feed all of them. So most of the deer starved to death. Those that lived ate far too many plants.

People found out that it was not wise to remove all the predators from a community.



Adding a new member. Just as removing a member can cause change in a community, so can adding a member!

In 1869 a few gypsy moth eggs were brought to North America from Europe. Before that time there had never been a gypsy moth in this country. The people who brought them were searching for a better silk-producing moth. But the gypsy moths did not prove to be good silk producers. Worse yet, some escaped from the place where they were being tested.

A hundred years later, gypsy moths had spread throughout the northeastern United States. There, they cause more and more damage every year. Gypsy moths ate every leaf on the trees in the picture below.

Gypsy moths have affected other members of the woodland community. Birds no longer can build safe nests in the trees. The baby birds are not well protected from predators and might die from too much sun. Some other animals, too, are no longer able to find protection in the trees. Even deer, who feed on low leaves, cannot find enough food.

Can you think of any other organisms that might be affected by the gypsy moth?

SOMETHING TO DO

Many other organisms have been introduced into our country. Some were brought in on purpose, but others were brought in by accident. Some have been helpful in certain ways. But others have been serious mistakes.

What can you find out about each of the organisms shown below? How and when was it introduced? How important is it now? Tell whether you think its introduction was a mistake or not. Explain your answer.

Starling

Honeybee

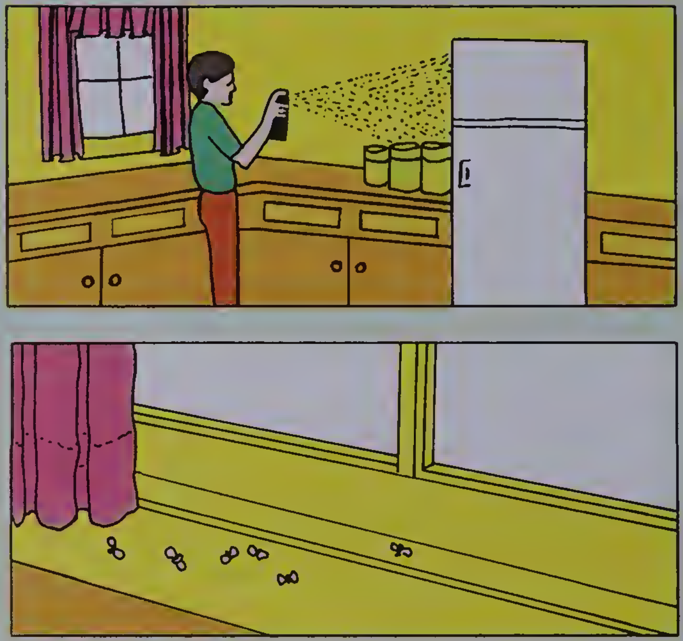
Corn borer

Japanese beetle

A PROBLEM

Suppose a North American scientist finds that a tiny European wasp kills gypsy moth caterpillars.

What things should the scientist be sure of before bringing these wasps into the country?



Poisons in food chains. Poisons often are used to kill insects. However, these poisons can be dangerous to other organisms. The chemical used to kill houseflies can also kill ladybird beetles and honeybees. These insects are helpful to us. The poison may kill animals that are not insects!

In general, poisons cannot "choose" which animals to kill. They just kill whatever small animal they get in or on.

Poisons are very harmful in long food chains. Much of the food consumers eat is lost as water, waste, and energy for living. But the poison from sprays often remains in their bodies. It builds up, or *accumulates,* as more and more poison is eaten. Poisons may accumulate to dangerous levels in some fish and in animals that eat fish.

Poisons are necessary at times. But they should be used with care.

SOMETHING TO TRY

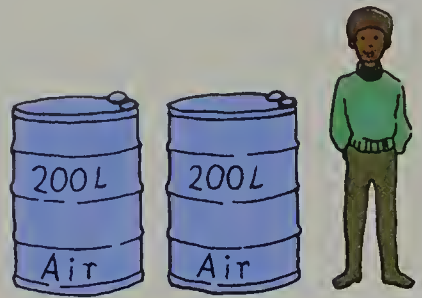
Find out what an insect spray really kills. On a warm, nearly calm day, spread newspapers on the ground under a bush. Then use an insect spray to thoroughly spray the bush. Be sure that you use a spray with a label that says the spray is not harmful to plant life. At the end of an hour, collect and look at all the living things that have dropped onto the papers.

How many different kinds of organisms did the insect spray kill? What kinds did you find that were not listed on the can? Were any killed that might not be harmful? Any that are not even insects? Does the spray seem to choose certain insects? Or, does it kill more than you think it should?

Safety Note: *Be careful not to inhale any of the insect spray while you are using it.*

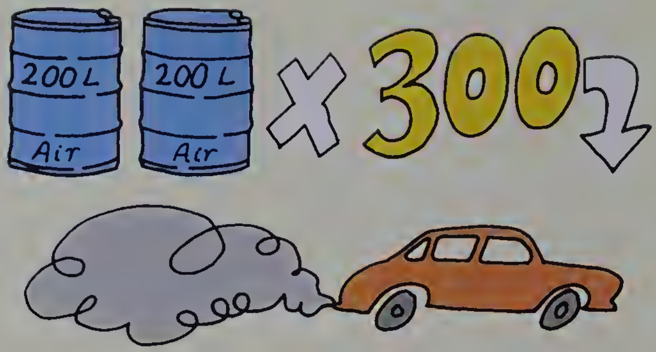
Interdependence with the ocean. Sometimes interdependence is so complex that it is hard to imagine. For example, how are you—or cars—interdependent with the ocean community? Let's see. . .

With each breath, you take in about 500 mL of air. This amounts to about 400 L per hour.



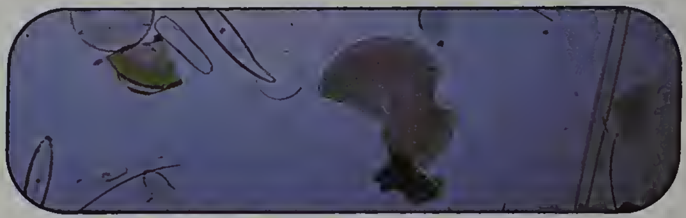
However, only one-fifth of the air you breathe is oxygen. And only about one-fourth of this oxygen is used by your body.

How does the oxygen you use compare with the oxygen a car needs? A full-size car going 90 km/h, uses about 300 times as much air as you do. Engines that burn fuels need a lot of air. They use more of the oxygen in that air, too!



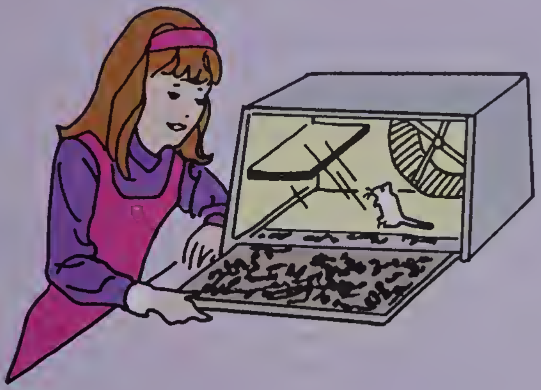
Is there enough oxygen in the air to supply people and machines forever? To supply other living things, too? Do you think any of the oxygen they use is being replaced? How?

Some of the oxygen we use comes from green plants on land. But much also comes from those in the ocean! About three-quarters of the earth is covered by water. Millions of algae live there. They probably produce more oxygen than green land plants do. Some algae are shown below.



Suppose there were no such sources of oxygen on the land or in the sea. Then, in time, there might be less oxygen for breathing than there is now. Less for burning fuels, too. But algae, grass, and trees help to replace the oxygen we take from the air. Can you see how you—and cars—depend, in a way, upon the ocean?

The ocean and people's waste. When you keep a pet, what care must you give it? You must feed it. You must give it water and exercise. You also must get rid of its waste. Even the cleanest of pets, like all animals, produces waste.



People produce waste, too. Much of their waste is liquid. Some comes from the people. Some comes from their factories. Where does all this liquid waste go?

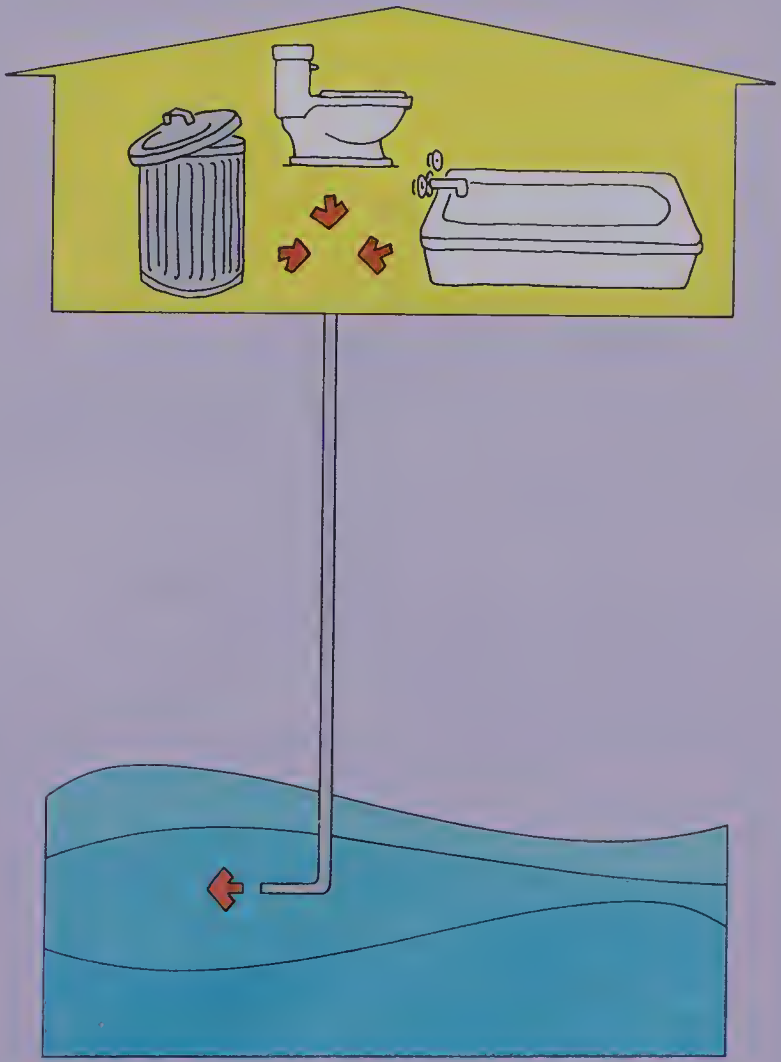
It goes down drains and into underground pipes. Some goes to a place where it is treated with chemicals. But in time much of it enters rivers or lakes, and finally some of it gets to the sea. There the waste interacts with the organisms in the sea.

Some of the chemicals in human waste are recycled. They help certain organisms to grow and to reproduce.

But other chemicals in the waste are harmful. Sometimes, large numbers of a certain kind of organism may be killed by the waste.

People and machines make use of the oxygen produced in the ocean community. The ocean community, in turn, is affected by the chemicals people put into the ocean.

Many people live so far from the ocean that they may never see it. But all people are, in some way, interdependent with the ocean.



Interdependence and Limits LESSON 6

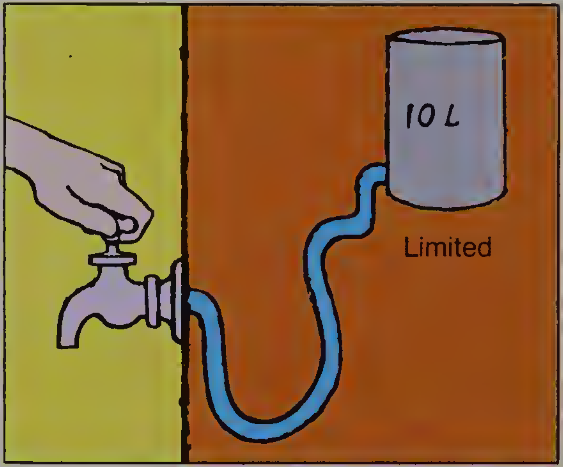
Most people think of the ocean and its products as going on forever. They think of it as an unlimited supply. They cannot see what might happen to the ocean because of their actions. It is too large. So they do not think about what or how much they put into it! Or take out of it!

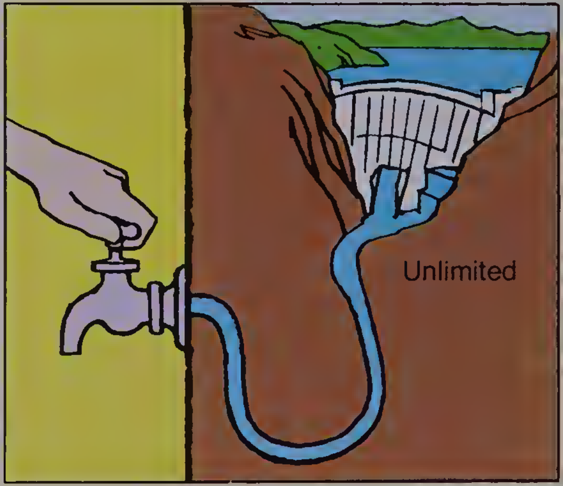
Often, people are more careful about their own back yards. There they can see what happens because of their actions. So can others. The whole yard is in plain sight. They think about what they do to it!

You may think of the water in a faucet as unlimited, too. Even though there may be a *limit* to the supply, you cannot see it. But suppose that you had only a small can of water to last a week. Then you would have to be careful not to waste any. When the supply of something you need is limited, you usually do not waste it.

People tend to care about
- things they can see
- things that are theirs
- things that seem limited

People tend *not* to care about
- things they cannot see
- things that are not theirs
- things that seem unlimited





In this market there are

- plenty of groceries
- plenty of shoppers
- plenty of check-out counters

But the store will not sell many groceries. There are only two clerks. The number of clerks is a *limiting factor*. It limits the amount of goods that the store can sell.

Do you remember reading about the marsh with its ducks, turtles, and skunks? Probably there was plenty of food for the ducks. But it was the number of skunks that limited the number of ducks. The skunks were a limiting factor.

Suppose that there were nine clerks in the store now. Then what do you think the limiting factor might be?

Ideas for REVIEW

- Almost all kinds of organisms in a community are interdependent.
- What happens to one organism often affects others in the same community.
- Interdependence is not always obvious!
- Interdependence may be simple, as in the case of a lichen. However, most times interdependence is not simple, it is complex.
- Green plants are the earth's producers.
- Nearly all other organisms are, in some way, consumers.
- Most food chains begin with green plants.
- At each link, only a tiny bit of the food becomes part of the consumer.
- Bacteria and fungi represent the last link in nearly all food chains.
- The chemicals in food chains are recycled.
- Poison chemicals can build up in a predator.
- Each kind of organism has certain needs. It gets the things it needs in a certain habitat.
- Any new organism must be studied carefully before being released into a community.
- Almost everything that an organism needs is limited in some way. People are constantly looking for ways to remove limits.

TEST Your Understanding

A. Choose a word from column B that best matches the words in column A. On a piece of paper, write the letter of the word next to the number it matches. Not all the words are used. *Do not write in this book.*

A

1. place where an organism lives

2. vultures, flies, cockroaches

3. simplest green plants, no roots, stems, or leaves

4. the first link in any food chain

5. all the living things that interact in an area

6. the thing in shortest supply

7. last link in a food chain

8. organism that eats, but does not make food

9. animals that catch and eat other animals

10. leaf → earthworm → robin → Cooper's hawk

B

a. algae

b. decomposers

c. community

d. lichen

e. food chain

f. habitat

g. interdependence

h. limiting factor

i. predators

j. producers

k. scavengers

l. consumers

B. On your paper, write the best answer to each of the following questions.

11. Which of the following is a producer?
- **a.** chicken
- **b.** alga
- **c.** minnow

12. Which of the following is a consumer?
- **a.** alga
- **b.** corn
- **c.** cow

13. Which of these organisms would be at the top of a pyramid of numbers?
- **a.** mouse
- **b.** frog
- **c.** lion

14. Which two living things form a partnership called a lichen?
- **a.** bacteria and fungus
- **b.** alga and bacteria
- **c.** alga and fungus

15. Which example does *not* show the correct order for a food chain?
- **a.** corn → chicken → human
- **b.** grass → cow → human
- **c.** chicken → corn → cow

Leaf

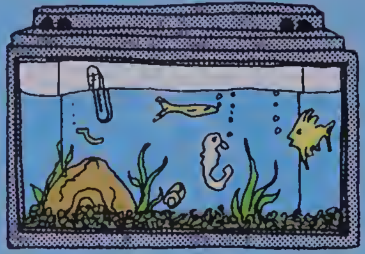
Earthworm

Robin

Cooper's hawk

PROBLEMS

1. What limits
- the number of balloons this boy can buy?
- the size to which these fish will grow?
- the number of fish the tank can hold?

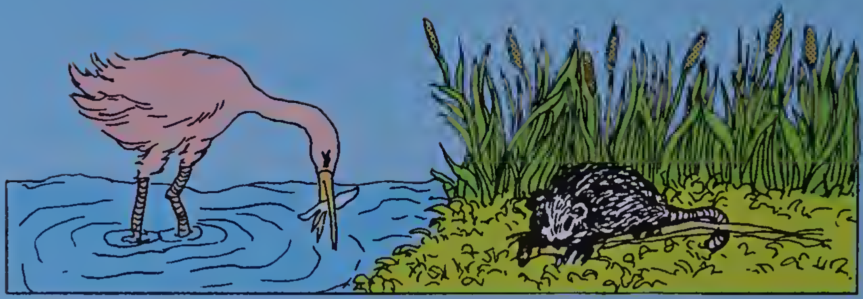


In each case, you described a limiting factor. Suppose what you described was not a limiting factor. What else might have become one?

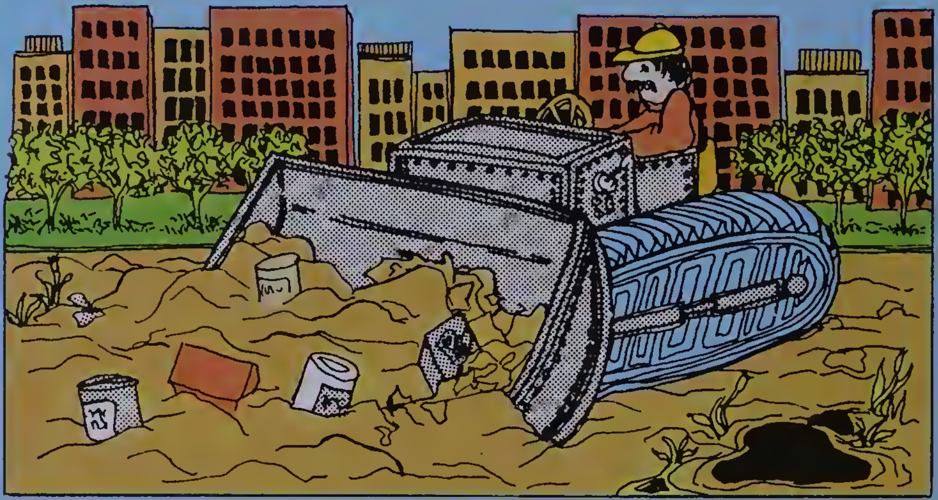
2. Imagine that on a far-away island there is an insect-like animal called a *ferrosome*. It has a tough body that is hard to crush. It has six legs, but no wings. A ferrosome can crawl or swim up to 1 km but cannot fly. It reproduces rapidly. And insect sprays do not kill it!

Ferrosomes kill houseflies by spraying them with a poison.

A scientist finds ferrosomes very interesting and wants to study them. What should the scientist think about before bringing some of them into this country?



3. Suppose that the muskrat eats mostly plants. The heron is a predator at the end of a long food chain. In which animal do you think more poisons could accumulate? Why do you think so?



4. Some people thought this swamp should be filled with trash. In time, the water habitat was gone. Of the changes that happened, which
- helped people?
- were not helpful to people?

Which of these changes could not be reversed? Why do you think so?

FIND OUT on Your Own

Find out what people in your community know about certain things in your environment.

Working with your classmates, write down a few questions to ask about the environment. Pick questions that have definite answers. Then pick 10 or 12 people from different parts of the community. Be sure to ask each person your questions in exactly the same way. Why?

Write down what the people say. Bring their answers to class and share them with others. Do you and your classmates agree with what some of the people in your community think?

Here are some ideas for questions.

- What happens to the trash in your community? How much longer do you think that this method can be used? Of all the things in your trash, which takes the longest to break down?
- How much water do you think you use in a 24-hour day? Where does it come from? Where does it go when you get rid of it?
- Should there be a limit on the amount of poison that people use on insects? Why?
- Should people be limited on the places they can use poisons? Why?

Glossary

The pronunciation is given for each word listed in this glossary. The stressed syllable in a word appears in capital letters.

The list below shows you how to use the symbols in the glossary to pronounce words.

Letter	Example	Spelling	Letter	Example	Spelling
a	cat	KAT	i	him	HIM
ah	Brahms	BRAHMZ	ī	kite	KĪT
ar	car	KAR	o	dog	DOG
ay	say	SAY	ō	hole	HŌL
e	hen	HEN	oo	moon	MOON
ee	meet	MEET	or	for	FOR
er	her	HER	u, uh	sun	SUN
g	grass	GRAS	z	zebra, runs	ZEE-bruh, RUNZ
j	jam, gem	JAM, JEM	sh	she	SHEE
k	kiss, cat, quick	KIS, KAT, KWIK	th	think	THINK
s	so, cent	SO, SENT	zh	measure	ME-zher

amphibians (am-FIB-ee-unz). animals that live on land and in water. Some have tails, 20.

anemometer (an-uh-MOM-uh-ter). an instrument used to measure wind speed, 180.

arachnids (uh-RAK-nidz). arthropods with "book-lungs" and eight walking legs, 28.

arthropods (AR-thrō-podz). invertebrates with jointed legs, 24.

atoms (A-tumz). bits smaller than molecules, 97.

bacteria (bak-TEER-ee-uh). certain one-celled living things, 284.

bedrock (BED-rok). solid rock under the ground, 42.

birds (BERDZ). warm-blooded animals that fly. All birds have feathers. Birds' eggs have hard shells, 16.

cells (SELZ). tiny building blocks that make up all living things, 115.

chemical changes (KEM-ik-ul CHAYN-juz). changes that make new materials, 91.

chlorophyll (KLOR-uh-fil). green matter in leaves, 34.

circulatory system (SER-kyoo-luh-tor-ee SIS-tum). the blood system. It includes the heart, arteries, capillaries, and veins, 124.

clay (KLAY). matter with particles smaller than sand or silt particles, 45.

community (kuh-MYOO-nuh-tee). all of the living things in an area, 302.

compound (KOM-pownd). material that has more than one kind of atom chemically joined together, 101.

cone-bearing plants (KŌN BAYR-ing PLANTS). plants that have their seeds growing in cones, 32.

conglomerate (kon-GLOM-er-ut). a rock made of pebbles cemented together, 51.

conservation (kon-ser-VAY-shun). the wise use of materials, 73.

convection (kon-VEK-shun). a cold fluid pushing a warmer, less dense one away, 169.

crustaceans (krus-TAY-shunz). arthropods with hard coverings, more than six jointed legs, and gills, 28.

digestive system (di-JES-tiv SIS-tum). where food is broken down. It includes the mouth, esophagus, stomach, liver, and intestines, 115.

electromagnets (ee-LEK-tro-MAG-nets). magnets made with electricity, 157.

element (EL-uh-ment). material with molecules that have only one kind of atom, 101.

enzymes (EN-zīmz). chemicals that help in digestion, 116.

evaporate (e-VA-puh-rayt). change from liquid to gas, 88.

fish (FISH). vertebrates that live in water, 21.

flowering plants (FLOW-er-ing PLANTS). plants that have their seeds in flowers, 32.

fluids (FLOO-idz). liquids and gases, 168.

food chain (FOOD CHAYN). a series of foods and feeders, each in turn, 289.

forces (FOR-sez). pushes and pulls, 151, 222.

fossils (FOS-sulz). remains of plants and animals in rock, 60.

fossil fuels (FOS-sul FYOOLZ). fuels such as natural gas, oil, or coal that were formed mostly from plants and animals of the past, 71.

fungi (FUN-jee). nongreen, seedless plants that feed on other organisms or dead matter, 34.

genus name (JEE-nus NAYM). a name for a group of organisms that are similar. A genus name has a capital letter, 36.

gravity (GRAV-uh-tee). the force between objects and the earth that causes objects to have weight, 230.

habitat (HAB-uh-tat). the place where an organism lives, 297.

hypothesis (hī-PO-thuh-sis). a possible explanation, 58.

insects (IN-seks). six-legged arthropods, 26.

invertebrates (in-VER-tuh-braytz). animals without backbones or bony skeletons, 23.

light beam (LĪT BEEM). light that takes the same path, or nearly the same path, 194.

limestone (LĪM-stōn). a rock made of shells cemented together, 51.

litmus paper (LIT-mus PAY-per). paper used to test for acids or bases, 94.

lodestone (LŌD-stōn). a piece of mineral that is a natural magnet, 139.

magnetic compass (mag-NE-tik KUM-pus). a freely-turning magnet that shows direction, 145.

magnetic fields (mag-NE-tik FEELDZ). places where the force of a magnet can be detected, 153.

magnetic shield (mag-NE-tik SHEELD). a material that blocks the pull of a magnet, 142.

mammal (MAM-ul). a warm-blooded animal that feeds its young with milk, 14.

mass (MAS). the amount of matter in something, 85.

meteorites (MEE-tee-uh-rīts). pieces of metal or rock from space, 276.

molecule (MOL-uh-kyool). the smallest possible particle of a matter that still has the properties of the matter, 96.

mudstone (MUD-stōn). a rock made of hardened mud, 51.

neutral (NEW-trul). said of material that is neither an acid nor a base, 94.

orbit (OR-bit). a path in space, 261.

organism (OR-guh-niz-um). a living thing, 6.

oxygen (OK-suh-jen). one of the gases in the air, 120.

phases (FAY-zuz). shapes of the moon, 271.

physical change (FIZ-ik-ul CHAYNJ). a change in shape, 87.

poles (PŌLZ). the places on a magnet where materials stick best, 143.

reptiles (REP-tīlz). animals with scaly bodies, such as lizards and turtles. Reptiles are not warm-blooded, 18.

respiratory system (RES-pi-ruh-tor-ee SIS-tum). the system that helps you take in oxygen. It includes the lungs and the diaphragm, 120.

rotation (rō-TAY-shun). turning, 262.

sandstone (SAND-stōn). a rock made of grains of sand cemented together, 51.

sediment (SED-uh-ment). material that settles, 48.

sedimentary rocks (SED-uh-MEN-tree ROKS). rocks made of hardened sediment, 51.

shale (SHAYL). thin, flat pieces of mudstone, 51.

silt (SILT). matter with particles smaller than sand grains, 45.

species names (SPEE-sheez NAYMZ). names for different groups of a genus, 36.

spinal cord (SPĪN-ul KORD). a bundle of nerves connecting the brain to other parts of the body, 10.

vector (VEK-ter). an arrow used to show force, 225.

vertebrae (VER-tuh-bray). bones in the backbone, 9.

vertebrate (VER-tuh-brayt). an animal with a backbone, 9.

volcanic ash (vol-KAN-ik ASH). a sediment of fine rock dust, 55.

volume (VOL-yoom). the amount of space something takes up, 85.

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